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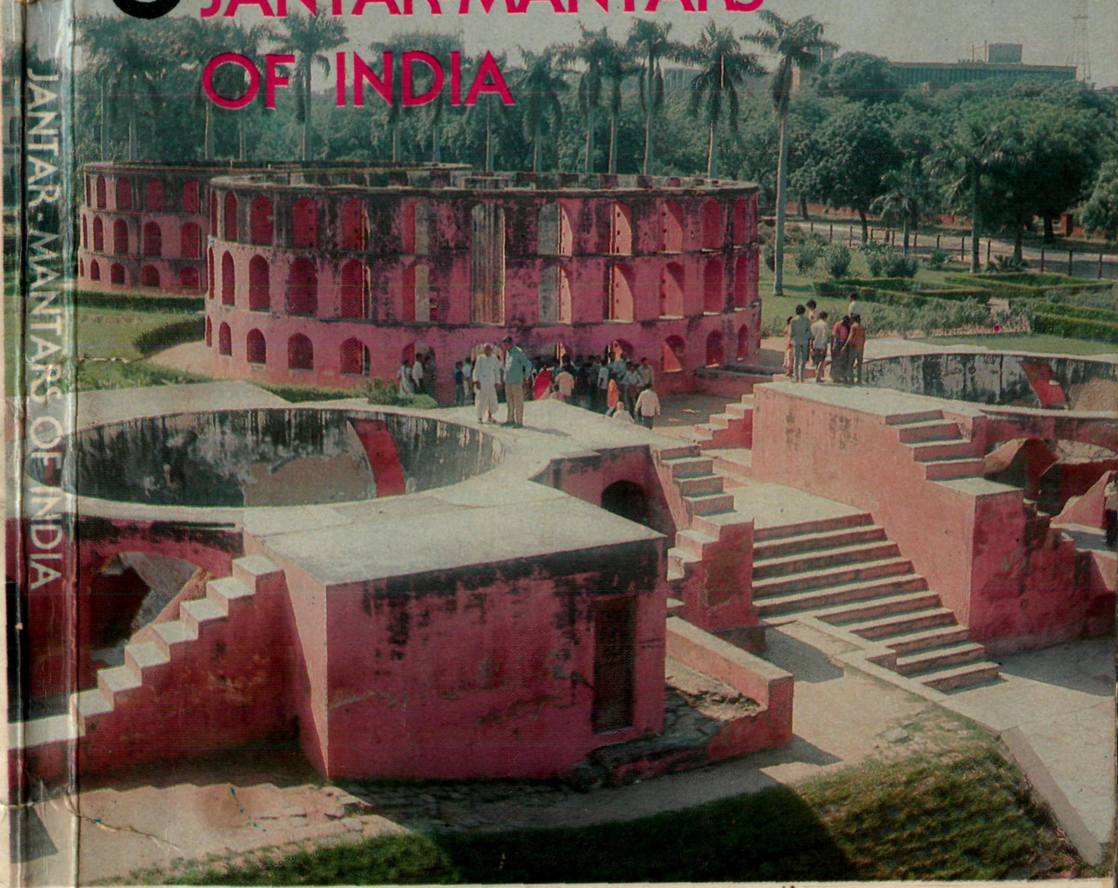
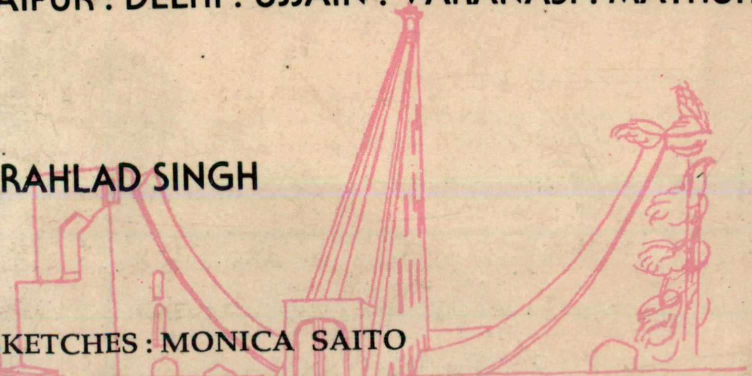
JANTAR-MANTARS OF INDIA

PRAHLAD SINGH

5 "STONE OBSERVATORIES" JANTAR-MANTARS OF INDIA



JAIPUR : DELHI : UJJAIN : VARANASI : MATHURA



PRAHLAD SINGH

SKETCHES : MONICA SAITO

FOREWORD : DIRECTOR, ARCHAEOLOGY & MUSEUMS

CONTENTS:

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FOREWORD

JANTAR-MANTARS OF INDIA (STONE-OBSERVATORIES) by Shri Prahlad Singh is a welcome and valuable addition to the relatively meagre literature on the subject. I believe the book would be of interest to a wide circle of readers.

There is now an increasing and deepening interest in the history of Indian Science and technical inventions, extending over a very long time. For a proper understanding of the social and political history of a country, a knowledge of the history of science and technology is of the utmost importance. Again, there has always been an active inter-action and cross-fertilization between scientific and technical developments in different parts of the world: the flow of ideas and discoveries cuts across all barriers. Much has been written about the history of Western ancient and medieval science, and yet in true sense the history of Western science will remain incomplete without an adequate knowledge of the growth of science in the East, and India specially. To some extent this aim has been achieved by the author of the present monograph as this work covers one of the most important aspects of scientific advancement made by Indians in the field of Astronomy. This book deals in detail with all five astronomical observatories and their intricate instruments built by Maharaja Sawai Jai Singh II of Jaipur during the eighteenth century. The Maharaja is well known for his keen interest in astronomical studies. In fact these astronomical observatories are the unique monuments of

tremendous scientific and educational significance which have become great symbol of our national heritage.

I hope Shri Prahlad Singh's present work will contribute significantly towards a more sustained study and research so that at not too distant future, we have much fuller, documented and integrated account of land marks in the history of astronomical science in India.

(P.L. Chakravarty)
Director,
Archaeology and Museums,
Rajasthan,Jaipur.

June 17th,1986.

About the Author & his books

PRAHLAD SINGH is the first Indian to write 'STONE OBSERVATORIES IN INDIA', describing in detail the Indian astronomical instruments right from the Vedic time to that of Maharaja Sawai Jai Singh II who took observational astronomy to Olympian heights in India during tne eighteenth Century. He has also written two pocket-books on JAIPUR OBSERVATORY in English and French.

The present book, fourth in his series on Stone Observatories, is the abridged and simplified paper-back edition of his earlier detailed work on Indian Observatories of yore. Through his books, he has tried to give a new dimension to this academic subject and has embossed these astronomical monuments on the world tourism map.

Through the present work, the 'JANTAR MANTARS OF INDIA', he has endeavoured to make these wonderful astronomical monuments of the country more popular and better understood by the Indian and foreign tourists visiting them as well as the young student community and general readers. He also hopes that such publications would attract the attention of all concerned to save these magnificent science monuments from decay and deterioration as he claims that the stone observatories of India are still the best among the similar monuments located in Central Asia, Iran etc where most of them are restricted

to the pages of history only. In fact, one of the five Indian observatories at Mathura is already extinct. The other four at Jaipur, Delhi, Ujjain and Varanasi deserve the utmost attention and care for their preservation for the posterity.

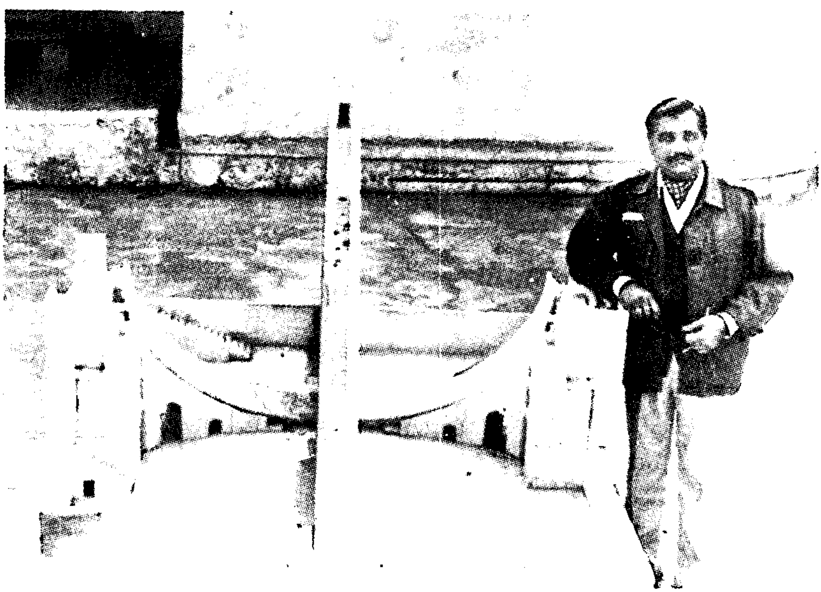
Son of K. Gulab Singh of the Shekhawat clan of former Jagirdars of Chandana (Shekhawati) in Rajasthan, the author graduated from the University of Rajasthan, Jaipur, from where he obtained Diploma in French and German languages. He has also a Post-Graduate Diploma in Tourism and Hotel Management of the same University.

Trained and recognised by the Department of Tourism, Government of India, he is engaged in the dynamic field of tourism as a Free-lance Linguist Tour Guide/Escort/Interpreter. His services to French tourism were duly rewarded by the famous JET Tours of Paris which invited him to France in 1976.

His other ventures include research, writing, publishing, photography and agriculture farming. A member of the INTACH (Indian National Trust for Art and Cultural Heritage) and the Joint Secretary of TWSI (Tourism & Wildlife Society of India) - an NGO engaged in the promotion of tourism and conservation of wildlife, Mr. Singh has attended two international conferences

on Bustards at Jaipur, and the CITES (Convention on International Trade in Endangered Species) at New Delhi.
After the Jaipur conference, the TWSI succeeded in getting the highly threatened desert birds (Great Indian Bustards) fully protected and declared as the "State Bird" of Rajasthan by the Government. These efforts have been much appreciated by the international conservation organisations.

A lover of ancient observational astronomy, the author continues his research of the Stone Observatories of the world.



ACKNOWLEDGEMENTS

I am grateful to Pandit Kalyan Dutt Sharma, former Officer in-Charge of the Jaipur Observatory, for his invaluable guidance in understanding the technical aspects of the observational devices. My thanks also go for Pandit Om Prakash Sharma, the present Officer-in-Charge of the Observatory, who has always been helpful in consultations. I am indebted to my friend Mr. Harsh Vardhan, General Secretary, Tourism & Wildlife Society of India, for his all-round help for this publication. I extend my sincere thanks to Mrs.Monica Saito, the artist from Zurich, Switzerland, for sketching out the astronomical instruments and also to Mr. Gopal Namjoshi for sketching the site plans etc for the book. I express my gratitudes to Mr. P.L. Chakravarty, Director, Archaeology and Museums, Government of Rajasthan; Mr. O.P. Korotania, Director, Government of India, Tourist Office, Jaipur, and his staff, and the Department of Tourism, Government of Rajasthan for their continued encouragement. I greatly appreciate the help rendered by Mr. B.P. Saboo for typing the MSS and Mr. Alok Jain of Jaipur Printers Pvt. Ltd., Jaipur, for printing the book.

Astronomer Maharaja SAWAI JAI SINGH II of Amber and Jaipur (1699-1743 A.D.) - The builder of five JANTAR-MANTARS OF INDIA.Courtesy-Maharaja Sawai Man Singh II,Museum Trust,City Palace, Jaipur.

MAHARAJA SAWAI JAI SINGH II - THE ASTRONOMER

In 1719 A.D., a noisy session was going on in Delhi's Red Fort Public Audience Hall. Moghul Emperor Mohammad Shah and Maharaja Sawai Jai Singh-II of Amber were silently witnessing the court Maulvis and Pandits; daggers were drawn among them for ascertaining certain astronomical calculations.

The Emperor had to embark upon a big expedition. Auspicious time to start the journey had to be determined. The controversy was rife about positions of certain planets which cast their influence on human life on the earth. There were no astronomical laboratories. available for verifying the calculations. The heated debate ended inconclusively but it did provide a thought to one of those present in the court - the Maharaja of Amber, who had already studied and acquired a good knowledge of astronomy and mathematics. Next morning, Sawai Jai Singh was strolling in his estate - Jaisinghpura. Mohammad Shah was on his morning trot. He found his noble lost in brooding, something uncommon at that morning hour. Sawai Jai Singh provided an answer to the inquisitive Emperor by announcing his decision to construct Astronomical Observatories and thus,educate the nation on a subject which was proving a Gordion's Knot many a time.

The Maharaja's proposal was accepted and the idea won him instant praise.

The Emperor said, "Since you, who are learned in the mysteries of science, have a perfect knowledge of the matter ..... you so labour for ascertaining the point in question that the disagreement between the calculated times of those phenomena and the times at which they are observed to happen may be rectified."

THE JOB DONE

By 1724 A.D., Sawai Jai Singh had completed his first Astronomical Observatory at Delhi, the place where controversy over platenary positions had made the Emperor doubtful about his expeditions. And thus, India witnessed, for the first time, massive stone and masonary instruments which enabled both amateurs and professionals to carry out the astronomical observations.

The Astronomer Maharaja also carried out his experiments and observations for nearly seven years at this epoch-making observatory.

As a result, he reformed the Imperial Calendar and established the value of the obliquity of the ecliptic as 23°28' which was so close to the correct value 23°27'. Besides, he compiled his results based on actual observations in his epoch-making tables entitled Ziz-i-Mohammed Shahi, honouring the Emperor, who patronised

the ancient science of astronomy.

THE INVENTOR AWARDED

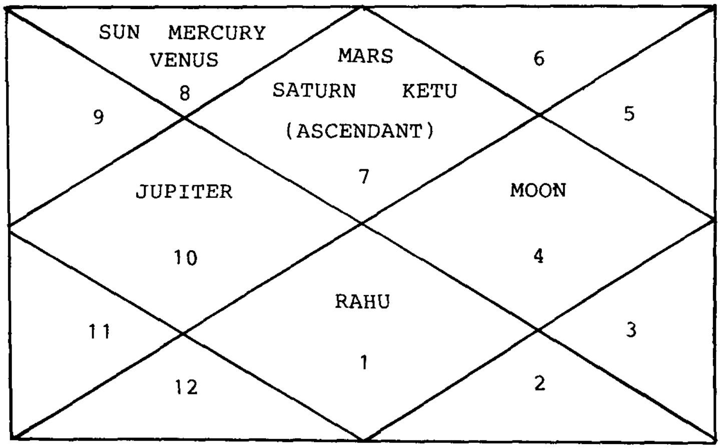
In turn, Emperor Mohammed Shah conferred upon Sawai Jai Singh the titles of Sar-Amad-i-Rajan-i-Hindustan, Raj-Rajeshwar, Shri Rajadhiraj, Maharaja Jai Singh Sawai and appointed him as the Governor of Agra and Ujjain (Malwa).

Sawai Jai Singh became immortal, not because of the high honours received at the Moghul court, but because of the Herculian task performed by him in erecting the stone observatories in India. It was the biggest-ever scientific exercise undertaken by anyone during this millenia. It elevated this prince to the highest pinnacle of glory, putting him in the choicest category of the few who had shed their sweat on astronomy, the most difficult of the difficult sciences.

BRILLIANT SON OF KACHHAWA DYNASTY

Jai Singh was born on 3 November,1688 A.D. at Amber, the fortified capital of Kachhawa (Kushwaha) rulers. The court astrologers had predicted to his father Raja Bishan Singh (Vishnu Singh) of Amber that his son would shine like Jupiter in the galaxy of princes and would prove to be the brightest star of the Kachhawa House.

Horoscope of Sawai Jai Singh II



Rahu (Dragon's Head or Ascending Node)
Ketu (Dragon's Tail or Descending Node)

According to the horoscopic positions, he was born under the Zodiac sign of Cancer with Libra ascendant which made him an ardent lover of art, architecture and sciences. Beside ascendant Libra, the Master of 4th and 5th Houses is Saturn which is also posted in the 1st House in top sign i.e. Libra. Thus, Saturn is the best placed planet in his horoscope which influenced his mind to be an able ruler, farsighted builder, technically minded, protector of people and above all, a super intellectual.

His visionary father made all arrangements for his early education, both in martial and academic subjects. After the untimely death of his father in 1699 A.D., Jai Singh was crowned as the

Raja of Amber at the tender age of 11. But he proved too smart for his age. Moghul Emperor Aurangzeb was impressed by his wit and chivalry to the extent of bestowing upon the young Rajput Ruler the title of "Sawai" - literally one and a quarter times more than his contemporaries - which still adorns his descendant Lt.Col. Maharaja Bhawani Singh, Sawai.

The young Maharaja was lucky enough to have a wise mother who made all out efforts to see her brilliant son grow in the shadow of learned tutors. Pandit Kewal Ram of Gujarat, Pandit Ratnakar Pundrik of Maharashtra and Pandit Vidya Dhar Bhattacharya of Bengal taught him religion, philosophy, art and architecture, whereas Pandit Jagannath 'Samrat' was his Guru for astral sciences and languages. Jagannath Samrat gave him intensive coaching of the ancient Hindu treatises on astronomy and mathematics, like the 'Surya Siddhanta', the master-works of Aryabhatta, Varahmihira, Brahmagupta and Bhaskaracharya. As a devoted student of astronomy, Sawai Jai Singh had a universal approach to the subject and learnt in detail about the foreign classics, viz., Ptolemy's Syntaxis (Almagest), De La Hire's Tabulae Astronomicae, Flamsteed's Historia Coelestis Britannica, Newton's Principia, Euclid's Elements, Mirza Ulugh Beg's Astronomical Tables etc.

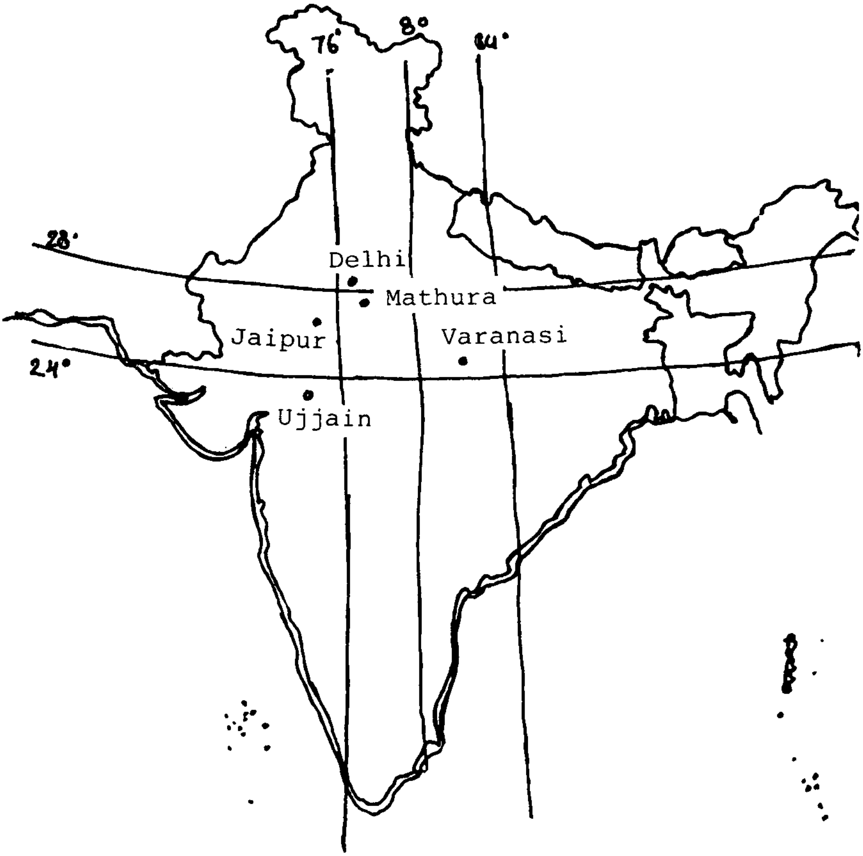
After having thoroughly been acquainted

with the Hindu, Greek, Muslim and European schools of astronomy, Sawai Jai Singh started giving concrete shape to his knowledge of the subject right from 1719 A.D., when he began to construct the first systematic astronomical complex at Delhi.

Meanwhile, he was also busy planning to execute his ambitious project of shifting his capital from the hilly Amber to a bigger and beautiful city, later to be named Jaipur after him in 1727 A.D.

It is said that the construction of the Ganesh Temple on the northern hill overlooking the city and the Jaipur Observatory had been taken up much before November 18,1727 A.D., the day foundation stone of Jaipur was laid. It is given out in records that the Jaipur Observatory was completed by 1728 A.D. when most of the royal buildings were still under construction. Within the next few years, Maharaja Sawai Jai Singh raised three more Observatories at Ujjain, Varanasi, and Mathura, and thus,became the only astronomer in the world to have constructed as many as five astro-observatories. His unprecedented achievement still remains unsurpassed

The conception and construction of five magnificent 'JANTAR MANTARS' in the count y was nothing short of a miracle considering the time which followed the



Map of India, depicting sites of all five observatories: Delhi, Jaipur, Ujjain, Varanasi and Mathura

death of Emperor Aurangzeb in 1707 A.D. Feudal clashes, rebellions and tumultous wars filled the scene in the wake of the death of the Moghal Emperor. The decay had set in for this empire. During this darkest period of the post-medieval India, Sawai Jai Singh stood like a rock to face all dangers to carry on his grand astronomical plans with prudence and perseverance.

By such unusual constructions, Sawai Jai Singh promoted the scientific approach to astronomy and astrology. To acquaint people with the scientific aspects of the universe and its unending phenomena, he provided these astronomical institutions at five important cities of India.

Also, he revived the ancient Hindu astronomy by stressing the importance of actual observations through human eye, unaided by any telescope. On the basis of his practical observations, he reformed the existing calendars, corrected Ulugh Beg's tables, and compiled the famous Zij-i-Mohammed Shahi catalogue of stars and planets. He discovered the value of the obliquity of the ecliptic as 23°28' which is very near to the exact value 23°27'. His observatories served as laboratories where different calculations could be tested and verified by practical observations. These were and are still used to educate students by demonstrating various aspects of the

celestial events. In the by-gone days, these observatories served as venue for academic seminars, astronomical conferences and discussions and above all, for preparing authentic ephimeris, calendars and almanacs. Thus, his magnificent observatories have been great seats of learning.

It is interesting to know that most of the kaleidoscopic structures representing various astronomical devices are of Hindu origin though the technique of construction in masonary and stone is Islamic. The Maharaja was inspired by such astronomical constructions done by Ulugh Beg during the fifteenth century at Samarkand in Central Asia. However, while reviving traditional Hindu astronomy, he improved the existing techniques to achieve perfection and precision in celestial observations He preferred stone and masonary instruments to Europeans' and early Hindu's metal and wooden devices as the former was easy to graduate for more accurate observations and readings due to their large size and stable planes.

PROMOTION OF TOURISM

Sawai Jai Singh was proud of his scientific creations and he wanted the world to know about them. On hearing about the prestigeous construction, the PortugueseViceroy in Goa despatched

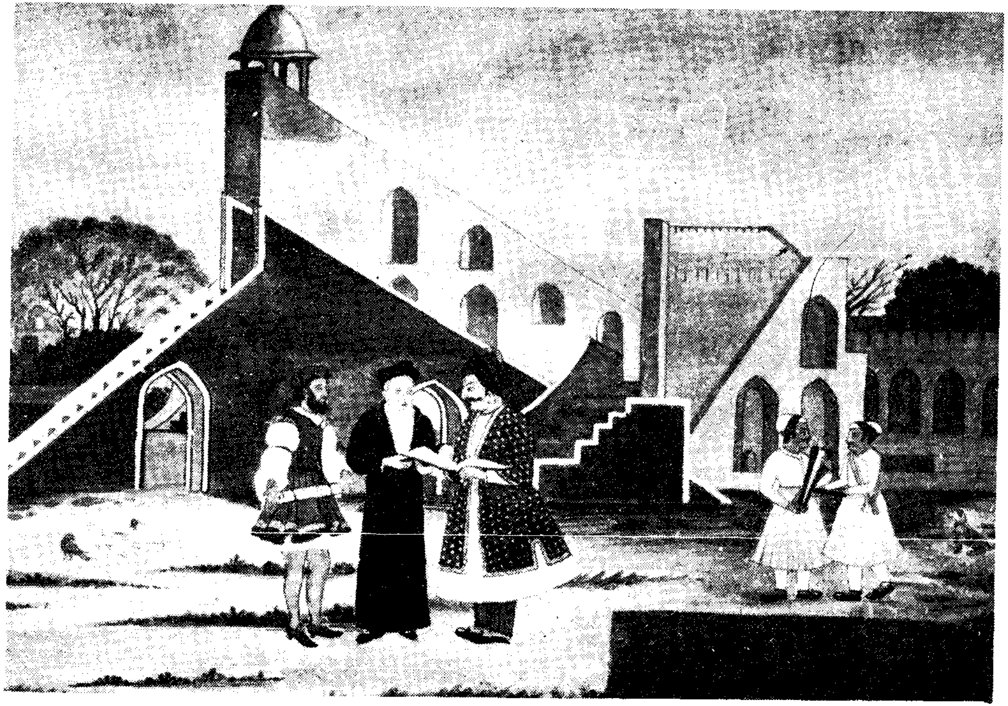
Padre Manuel de Figueiredo to Jaipur in 1729 A.D. He, thus, became the first European to visit Jaipur due to the observatory here. The Padre was given a familiarisation tour of the observatory by the host Maharaja himself. In turn, the Portuguese Jesuit presented His Highness the works of Copernicus, Galileo, Kepler, Tycho Brahe and Newton. Later, Padre Xavier de Silva also came to Jaipur to congratulate the Maharaja for his marvellous feat.

These dignitaries can safely be accepted as the FIRST TOURISTS to the city of Jaipur. The observatory, thus, was the first object in Jaipur to attract foreign tourism. To this date, this maze of monuments continues to be a Must in tourists' itineraries.

The news of the extraordinary astronomical planetarium of the Pink City spread fast throughout the European and Muslim countries. French Jesuits Père Claude Boudier and his colleague trekked from Chandernagore to Jaipur in 1734 A.D. The visit was followed by that of a Bavarian astronomer-priest Father Andre Strobel, Anthoine Gables Perger and Tieffenthaler.

Thus, the Jaipur Observatory became well known even outside India during its builder's lifetime. That was beginning of ASTRONOMICAL TOURISM. It con tinues.

The worthy descendants of the glorious



Maharaja Sawai Jai Singh conversing with Father Manuel De Figuerido S.J. and a Portuguese Fidalgo, who arrived from Portugal in 1729 A.D. The Father presented the Maharaja with some astronomical charts and books. They are seen in the grounds of Jaipur Observatory.

Astronomer Maharaja Sawai Jai Singh II of Jaipur have taken keen interest in promotion of tourism by converting their Royal Palaces into hotels and museum. The Rambagh Palace, The Raj Mahal Palace and The Jai Mahal Palace are coveted as deluxe hotels and the City Palace has become a remarkable museum where most of the books/ manuscripts collected and even written by the astronomer Maharaja can be seen among several other rare antiques and art objects.

Maharaja Sawai Jai Singh II passed away on 21st September,1743 A.D. at Jaipur. Thus,ended a glorious period in the Indian history. His successors paid a befitting tribute by constructing an exquisitely carved marble cenotaph in his memory at the Royal Crematorium at Gaitore in the north of Jaipur. The Maharaja was again remembered by the people of Jaipur when a life size marble statue along with the Sun Dial was erected at the Statue Circle near the State Secretariat. It was unveiled by the President of India on 10th May,1968. Above all, he is remembered by thousands of people every day who go round visiting his four existing Jantar Mantars in India which are keeping the flag of the Astronomer-Maharaja's glorious memory flying high.

A BRIEF NOTE ON MUSLIM OBSERVATORIES

The Muslims were zealous disciples of astronomy which they learnt from Greeks and Hindus. They were keen star-gazers who excelled even their masters in observational astronomy by raising the finest observatories of their times. The notion of increasing the size of the instruments to the maximum extent is undoubtedly of Muslim origin. To determine the precise time of the holy month of Ramadan in the Islamic Calendar, to chart out the star catalogues, prepare the lunar calendar and to locate the cities and routes to help the pilgrims travelling to Mecca, a number of astronomical observatories consisting of various stone and masonary instruments of large size were raised throughout the Muslim World from nineth to the fifteenth century.

The fundamental principles of Ptolemy (Almagest) were verified by actual observations at the BAGHDAD OBSERVATORY of Calif al Mamun (813-833 A.D.) An Arc of the Meridian was raised in the PALMYRA region in the nineth century. A few accurate masonary instruments adorned the GONDESHPUR OBSERVATORY in Persia also during the nineth century. The process of actual observation with the help of masonary devices continued like a chain reaction in the Muslim countries to finally reach India in the eighteenth century.

Some Arab works mention some of the large sized instruments of Abul Wafa who made a

Sextant of 20 feet radius in 995 A.D. The Sextant of Abu M. Khojendi (992 A.D.) was of about 60 feet radius. The CAIRO OBSERVATORY of the 10th century was used for compiling the HAKIMID TABLES.

While constructing the massive astronomical devices, the Arab astronomers excelled simultaneously in making the small metal devices particularly the Astrolabes which are still known as remarkable work of art and craftsmanship.

Persians of the medieval times played an important role in such astronomical constructions. The NISHAPUR OBSERVATORY (modern Neyshabur in Iran) was erected during the reign of Sultan Malik Shah in 1074 A.D. where a number of celestial observations were carried out by Al Khazimi and recorded in his SANJARID TABLES. Omar Khayyam, the famous Persian poet and astronomer prepared a set of astronomical tables, reformed the existing calendar and wrote a book on Algebra. Omar Khayyam also introduced the JALAI YEAR in 1074 A.D. at Nishapur.

One of the biggest Muslim observatories was constructed at MARAGHA - modern Maragheh (Tabriz) in Iran in 1259 A.D. during the reign of Sultan Bulagu. This magnificent observatory consisted of a Quadrant, Armillary Sphere, Meridian circle, an instrument on two pillars - a modified version of

Ptolemy's parallactic bars and a couple of Azimuth Instruments. Famous Persian astronomer Nasir al-Din al-Tusi made extensive observations with the above mentioned devices for astronomical calculations which he compiled in his ILKHAMID TABLES. Tusi also obtained excellent results by utilising a hole in the dome of a high building. This famous Persian astronomer is also referred to in the works of Ulugh Beg and Sawai Jai Singh.

The Turk monarch of Samarkand, ULUGH BEG (1394-1449 A.D.) was the son of Shah Rokh and grandson of the famous conqueror Timur the Lame. He took observational astronomy to new heights in Central Asia He was, perhaps, the most prominent astronomer of the Muslim World. As a young prince he visited Maragha Observatory during one of the military expeditions of his grand father, Timurlane. Already interested in astronomy, the Maragha pattern of stone and masonary instruments of huge dimensions inspired Ulugh Beg to construct a magnificent observatory of his own, which he accomplished at his capital Samarkand (Uzhbekistan U.S.S.R.) around 1425 A.D. His several stone and masonary instruments included a Meridian Arc of 40 meter radius which proved to be the world's largest astronomical structure of that time. Many prominent scholars like Jamsheed al-Kashi (also mentioned by Sawai Jai Singh), Khadi Zade al-Rumi and Ali

The bust of Ulugh Beg (1394-1449 A.D.), the famed Astronomer-monarch of Samarkand (Uzhbekistan, U.S.S.R.) where he built the most impressive stone observatory of medieval times in C.1425 A.D. After his death at the hands of his son, most of his astronomical instruments were destroyed due to feudal clashes and fanaticism.

al-Qusji were his contemporaries. Ulugh Beg undertook a complete revision of the star catalogue which he based upon his direct celestial observations. This catalogue of 1018 stars prepared in Tadzikh language came to be known as ZIJ GURAGONI. In 1447 A.D., he also discovered the obliquity of the ecliptic as 23°20' 17" with only a negligible error. The scientific study of astronomy almost ceased throughout the Muslim World with the assasination of Ulugh Beg by his son Abdul Latif in 1449 A.D. as fanaticism took over scientific research.

Some 250 years later Maharaja Sawai Jai Singh rose like a prominent luminary on the astronomical horizon of South Asia who illuminated the scene with his five stone observatories for the first and last time in India. As the City Palace Jaipur records reveal, the Maharaja sent his emissary to Maragha to report back to him about the astronomical instruments built by Nasir-ud-din Al-Tusi and obtained his Ilkhamid Tables prepared in 1259 A.D.

Sawai Jai Singh also sent his ambassador to Central Asia to bring information and charts about Ulugh Beg's observatory at Samarkand. If Mirza Ulugh Beg was inspired by the Maragha Observatory, Maharaja Sawai Jai Singh was influenced a great deal by both Maragha and Samarkand technique of astronomical construction in stone and masonary in spite of the Hindu base reflected in most of his observational devices.

The remnant of a lofty Sextant of Samarkand Observatory built by Ulugh Beg in C.1425 A.D.

Thus, the astronomical axis between Maragha, Samarkand and Jaipur which could rightly be termed as the golden triangle of STONE OBSERVATORIES is an interesting subject of research which would be of tremendous scientific, historical and educational significance.

ASTRONOMICAL TERMS

ASTRONOMY - The science of observation and determination of motions, distances and positions of the heavenly bodies in the celestial sphere.

STARS - Fixed large globes of intensely heated gas. They shine by their own light. The sun is a star.

PLANETS - Large spherical bodies which revolve round the sun in elliptical orbits. Mercury, Venus, Mars, Jupiter, Saturn, Uranus, Naptune and Pluto are planets. Earth is also a planet.

CELESTIAL EQUATOR - A great circle, drawn east to west, divides the celestial sphere into two equal parts known as Northern and Southern Hemispheres. The Sun comes on the celestial equator on 21 March and 23 September, making equal duration of day and night, known as Vernal Equinox and Autumnal Equinox respectively.

LOCAL CELESTIAL MERIDIAN - The great circle is drawn north-south through the zenith. The sun comes on this imaginary line at local (mid-day) 12 O'Clock every day.

ZENITH - It is the highest point in the celestial sphere above the observer. The Zenith Distance of celestial objects is measured in relation to this point.

DECLINATION - It is the angular distance of a heavenly object north or south of the Celestial Equator.

ALTITUDE - It is the distance of a heavenly body vertically above the horizon. It is measured through 90 degrees.

AZIMUTH - It is the horizontal angle between a heavenly body and the south-point of the horizon. It is measured westward through 360 degrees in horizontal plane.

CELESTIAL LATITUDE - It is the angular distance of a heavenly object north or south of the Equator.

CELESTIAL LONGITUDE - A co-ordinate in the ecliptic system, it is the angular distance of a heavenly body from the Vernal Equinox along the Ecliptic towards east measured from 0° to 360 degrees.

ECLIPTIC - It is a great imaginary circle, representing the apparent annual orbit of the sun upon the celestial sphere, caused by the actual revolution of the earth around the sun.

EQUINOXES - These are two points where the great circle of the Ecliptic intersects the great circle of Celestial Equator. This happens twice a year, on

the 21 March and 23 September known as Vernal Equinox and Autumnal Equinox respectively, causing equal duration of day and night

ECLIPTIC OBLIQUITY - It is an angle of 23 degrees 27 minutes made by the intersection of the ecliptic and equator circles.

ZODIAC CIRCLE - It is an eight degree wide belt around the ecliptic It is divided into 12 zodiac signs of 30 degrees each.

ZODIAC SIGNS - These are a series of 12 constellations along the Ecliptic Circle known after the living creatures. They are very important and interesting from astrology point of view

RIGHT ASCENSION - A co-ordinate in the equator system, it is measured from the Vernal Equinox eastward to the point where the hour circle of a star intersects the Celestial Equator.

JANTAR-MANTAR : It derives from YANTRA-MANTRA in Sanskrit. Yantra means instrument and Mantra stands for mysterious formulae for calculation or attainment In India, the Observatories are also known as Vedha Shala, Yantra Shala, Yantralaya and Yantra Mahal.

THE JAIPUR OBSERVATORY

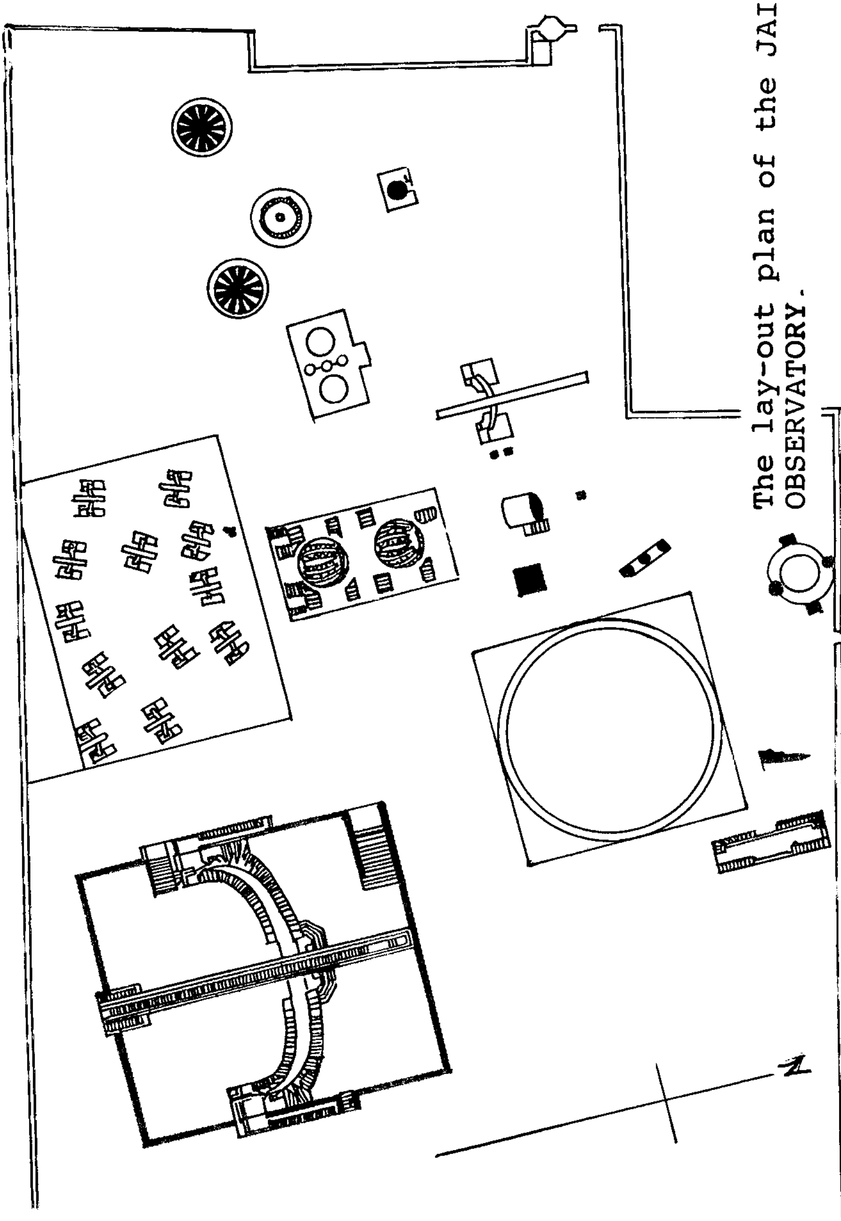
Altitude	431 Meters (1414 feet) above M.S.L.
Longitude	75° 49' 8.8" East of Greenwich
Latitude	26° 55'27" North.

After having experimented successfully with the masonary instruments at the Delhi Observatory by 1724 A.D., Maharaja Sawai Jai Singh decided to construct a bigger observatory at his new Capital Jaipur. He had already completed the blue prints and wooden and metal models of various astronomical instruments before he shifted his Capital from Amber to Jaipur. The construction of the astronomical observatory near the City Palace was launched upon much before 18th November,1727 A.D. when the foundation of Jaipur was laid. The observatory was completed by 1728 A.D. although its finishing touches might have taken a few more years.

Sawai Jai Singh's monumental love for astronomy found expression in the creation of this super observatory which soon became an institution of observational astronomy in India It is situated in the vicinity of the Royal City Palace to enable the Astronomer-Maharaja to carry out celestial observations whenever he wanted.

Maharaja Sawai Jai Singh beautified his new Capital Jaipur by this magnificent scientific creation which paved the way for the pursuit of astronomical studies and research in the country. The Jaipur Observatory became a venue for astronomical discussions held by Sawai Jai Singh with the Hindu, Arabian and European astronomers. To popularise the study of astral luminaries, to make celestial observations, to prepare the ephemeris, almanecs and calendars, Sawai Jai Singh erected the biggest of his five astronomical observatories at Jaipur. Astrological studies and forecasts and casting of horoscopes, based on the precise astronomical data collected with the help of various astronomical instruments, were also carried out here. This observatory still serves as an arena of practical demonstrations and examinations for the students of astronomy.

Sawai Jai Singh's court scholars and astronomers like Pandit Vidyadhar, Pandit Jagannath Samrat, Pandit Kewal Ram Sharma, Pandit Ratankar Pundarik were closely associated with the Jaipur Observatory which soon became the Mecca for the Indian and European astro-scholars Padre Manuel Figueiredo, Fidalgo and Padre Xavier De Silva, the Portuguese Jesuit Missionaries came to visit the Maharaja and his observatory in 1729 A.D. A German Scholar Andre Strobel and Don Pedro De Silva from Portugal also carried out observations here. French Jesuit-astronomer Pere Claude Boudier, along with



The lay-out plan of the JAIPUR OBSERVATORY.

a companion, undertook an ardous journey from Chandranagar (W.Bengal) to visit this observatory in 1734 A.D Some astro-scholars from Muslim countries also came here to compare their own stone observatories with that of Jaipur. Thus, the Jaipur Observatory became well-known out of India even during the lift time of its builder.

The Jaipur Observatory is surrounded by high walls Although situated in the heart of the now noisy city, it seems far from the madding crowd as a perfectly calm and quiet atmosphere, ideal for the contemplation of astronomical phenomena, prevails here. The observatory is in a very good state of preservation due to the keen interest taken by the worthy descendents of the Astronomer Maharaja This was restored under the orders of Maharaja Sawai Madho Singh II in 1901 A.D The restoration work was carried out under the supervision of Lieutinent R.E. Garrett, Pandit Chandra Dhar Guleri and Pandit Gokul Chand Bhavan. Since independence, it has become a National Monument and is looked after by the Archaeology Department of Government of Rajasthan.

Scholars of traditional astronomy and astrology Pandit Kedar Nath Sharma, Pandit Kanahaiyalal Shrimali, Pandit Durga Prasad Dwivedi, Pandit Girija Prasad Dwivedi. Pandit Laluji and Pandit Kalyan Dutt Sharma have been associated with this observatory since independence. Pandit Om Prakash Sharma is the present

officer-in-charge who is available for consultation on astronomical and astrological matters.

Popularly known as the JANTAR MANTAR, it is regarded as the world's largest, best preserved and most precise stone-observatory which finds its pride place in every visitor's itinerary. A life size or even a bust size statue of Maharaja Sawai Jai Singh, its builder, deserves to adorn the observatory

The State Government could do a great job by setting up an astronomical museum in the Observatory premises on the pattern of Samarkand museum dedicated to Ulugh Beg, its glorious Astronomer - Monarch of the fifteenth century. The Jaipur museum of astronomy could protect and exhibit a number of original wooden and metal models of various astronomical devices, which are getting rusted and dusted scattered around or dumped into the store. Such a unique museum could also depict various scenes of the astronomical life, books and charts etc. of the Astronomer-Maharaja of Jaipur.

NOTE:

Jaipur Observatory is a model observatory. Except a few, most of the instruments available at other observatories are identical in principle and function to those of Jaipur. Hence, the Jaipur instruments have been explained in detail

which would help the reader to learn about their counter-parts available elsewhere.

ASTRONOMICAL INSTRUMENTS AT JAIPUR:

1. THE SMALL EQUATORIAL SUN DIAL

KNOWN as the LAGHU SAMRAT YANTRA in Hindi, this red sand-stone and white marble instrument is seen on the left as a triangle based in the plane of local meridian and two quadrants on either side which are inclined by 23½ degrees in the plane of celestial equator. The hypotenuse of the triangle makes an angle of 27 degrees, equivalent to the latitude of Jaipur and is distinctly graduated in the scale of tangent used for measuring declination of heavenly bodies.

The quadrants are graduated in the time scale of hours, minutes and seconds - 6 to 12 O' clock (morning) towards west and 12 to 6 O' clock (evening) towards east. Each hour is divided by sixty minutes and each minute by three fractions, thus, making 20 seconds the precision of the time observed Each hour also stands for 15 degrees, meant for the Zenith Distance and Altitude observations.

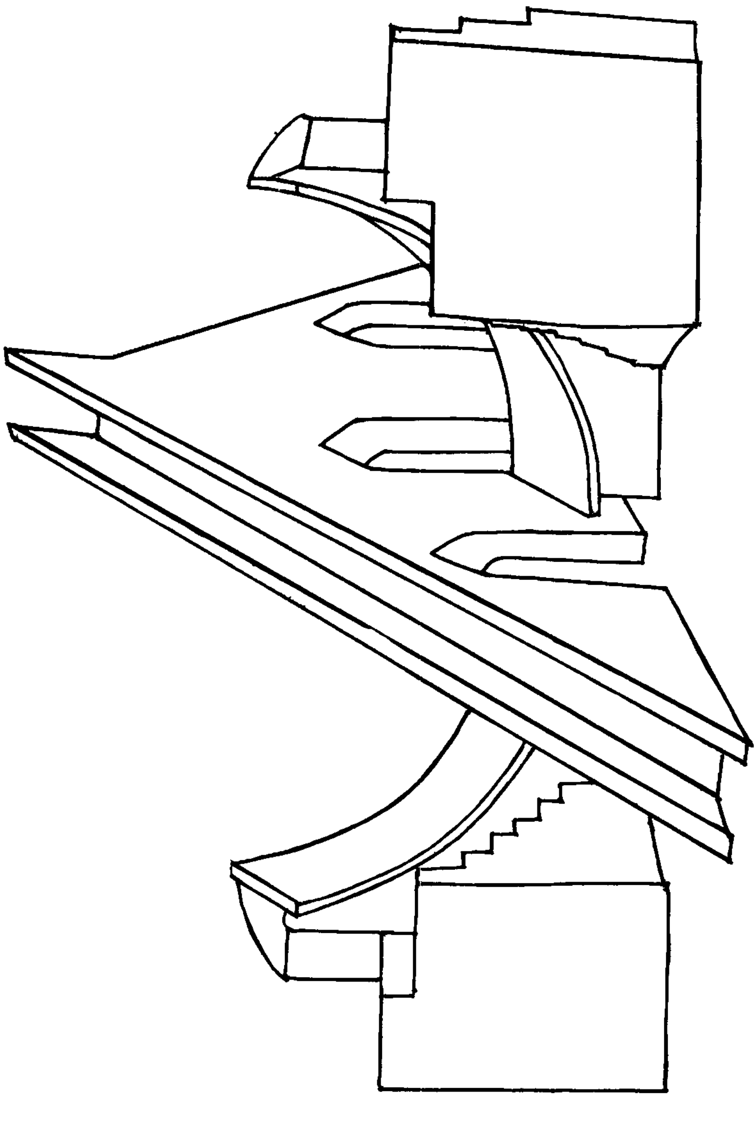
The table of Difference of Time of Jaipur and the Indian Standard Time is available at the Observatory office which is also published in this book.

The shadow of the hypotenuse (the gnomon) is observed on the graduated dials for reading the Local Time or the Solar Hour. The difference between the Jaipur Time and the Indian Standard Time varies from 10 minutes 25 seconds to 41 minutes 6 seconds which may be checked up with the Table of Time Difference. This difference of time is added to the time observed on the Equatorial Clock tc find out the Indian Standard Time.

The Meridian Pass Time of Sun can also be calculated in terms of time or degrees by observing the shadow of the gnomon falling on the quadrants. It may be remembered that there is no shadow on either of the dials at 12 O' clock (mid day) Local Time when the sun is at its zenith and crosses the Local Meridian due to the triangle's situation on the Local Meridian Line (north-south).

To determine the declination of the sun, a pointer is placed on the graduated hypotenuse(gnomon). Its shadow is seen intersecting the shadow of the gnomon already falling on the graduated quadrant below. This point on which the pointer is kept indicates the declination of the sun.

The same alignment is reached during night when no shadow is involved. The observer sits on the steps below keeping his eye on the edge of the graduated quadrant to see a star or planet through the edge of the hypotenuse. A pointer is placed on the graduated hypotenuse to make straight line of the celestial object with the eye of the observer. A thread is also utilised for such alignments and observations of the celestial declination.



The Small Equatorial Sun-Dial

TABLE OF DIFFERENCE OF THE TIME OF JAIPUR AND THE INDIAN STANDARD TIME

	5th Min.Sec.	10th Min.Sec.	15th Min.Sec.	20th Min Sec.	25th Min.Sec.	30th Min.Sec.
January	32.10	34.18	36.13	37.50	39.9	40 8
February	40.52	41.6	41.6	40.38	39 58	39 28
March	38.26	37.15	35.52	34.15	32.55	31.6
April	29.37	28.14	26.56	25.48	28.48	24.2
May	23.28	23.44	23.5	23.15	23.37	24.21
June	25.8	25	26.48	28.12	29.16	30.18
July	31.15	32.5	32.39	33.3	33.14	33.8
August	32.46	32.8	31.17	30.12	28.55	27.10
September	25.34	23.52	22.5	20.18	18.34	16.48
October	15.18	13.54	12.39	11.38	10.56	10.28
November	10.25	10.43	11.22	12.24	13.44	15.24
December	17.20	19.18	21.48	24.18	26.48	29 44

By adding this difference of time to the Local Time observed on the Samrat Yantra (Equatorial Dial) one can determine the Indian Standard Time easily and accurately. This difference of time is, however, invariable.

2. THE POLE-STAR INSTRUMENT

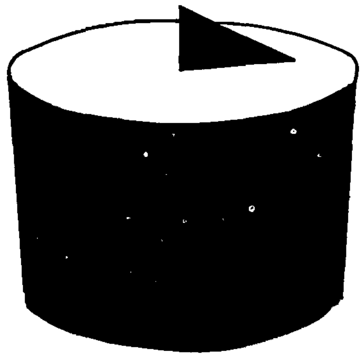
THE DUHRVA-DARSHAK YANTRA is situated eastward close to the Equatorial Sun Dial. Built in red sand-stone, this simple instrument indicates celestial North and helps the observer locate the Pole Star (North Star). The observer has to look towards the sky through its 27 degree slope to see the 'Dhurva Tara' twinkling amongst innumerable heavenly bodies in the firmament.

As various astronomical observations are done in relation to Pole Star, the astronomer Maharaja dedicated this instrument to the Guide Star.

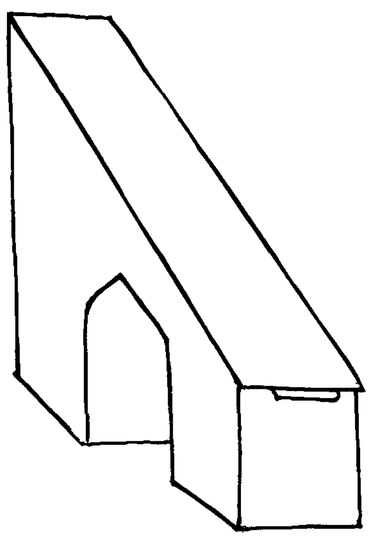
3. THE HEMISPHERICAL SUN-DIALS

KNOWN as the NARIVALAYA, these two Sun-Dials are made in the plane of celestial equator as they both are inclined by an angle of $23\frac{1}{2}$ degrees. They consist of two round structures representing the Northern and Southern Hemispheres. The northern face of the instrument functions as a Sun-Dial between 21st March and 23rd September when the sun is in the Northern Hemisphere, whereas the southern side is turned into a solar clock between 23rd September and 21st March evidently when the sun remains in the Southern Hemisphere.

The inner portion of the circular dial is graduated in 60 'ghatikas', whereas the circumference of the same has 24 hour markings, thus, making two and a



The Horizontal Sun-Dial



The Pole-Star Instrument

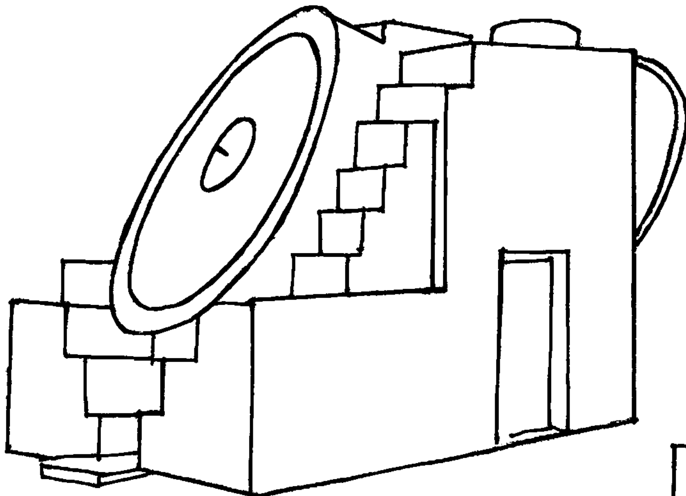
half 'ghatikas' equivalent to one hour. An iron-peg provided at the centre, serves as its gnomon whose shadow failing on the well graduated dial indicates the Local Time or the Solar Hour in 'ghatikas' and 'palas' as well as in hours and minutes. The precision of this Stone Watch is of one minute.

These Hemispherical Sun-Dials also indicate the hemispherical positions of heavenly bodies. If the observer stands in front of the Northern Dial facing the sky, he will see all the Stars and Planets when they are in the Northern Hemisphere and by standing in front of the Southern Dial looking at the sky, one can see the celestial objects when they are in the Southern Hemisphere. However, the South Star (Pole) is not visible from Jaipur due to its latitude of 27· degrees North.

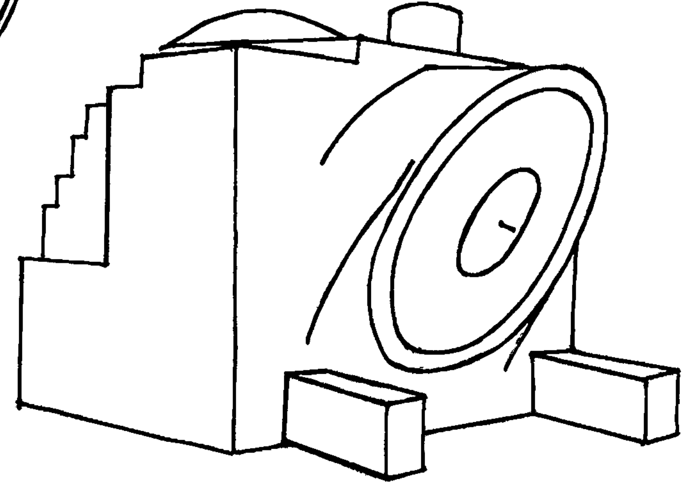
4. THE HORIZONTAL SUN-DIAL

ONE does not see this 'DHOOP-GHARI' until he climbs on top of the Narıvalaya, mentioned above.

Neatly graduated, the Horizontal Sun-Dial has a 27 degree triangular gnomon at its centre (North-South). Its shadow indicates the Solar Hour in 'ghatikas'. The time observed on this DhoopGhari may be verified by the Hemispherical Dials of greater dimension and accuracy, just below.



1. The Northern Hemispherical
   Sun-Dial



2. The Southern Hemispherical
   Sun-Dial

This is a very common type of Sun-Dial used in ancient times. Such dials can still be seen on the terrace of Amber Palace, Jaisalmer Fort and elsewhere in the dwellings of astrologer Pandits.

5. THE ECLIPTIC INSTRUMENT

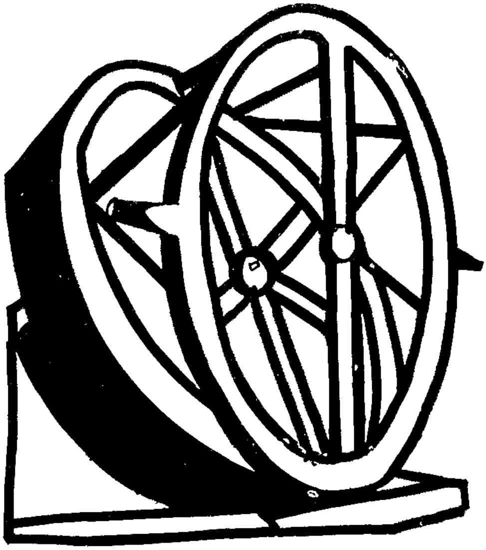
THIS 'KANTIVRITTA YANTRA' is situated north of the Northern Sun-Dial and is one of the few metal instruments of the Jaipur Observatory.

One of its two metal frames rests and rotates on a masonary base which is inclined to the plane of equator i.e., by $23\frac{1}{2}$ degrees, whereas the upper metal frame lies and rotates in the plane of ecliptic due to its inclination of $23\frac{1}{2}$ degrees. Thus, the metal frames and their masonary base put together make an angle of 47 degrees.

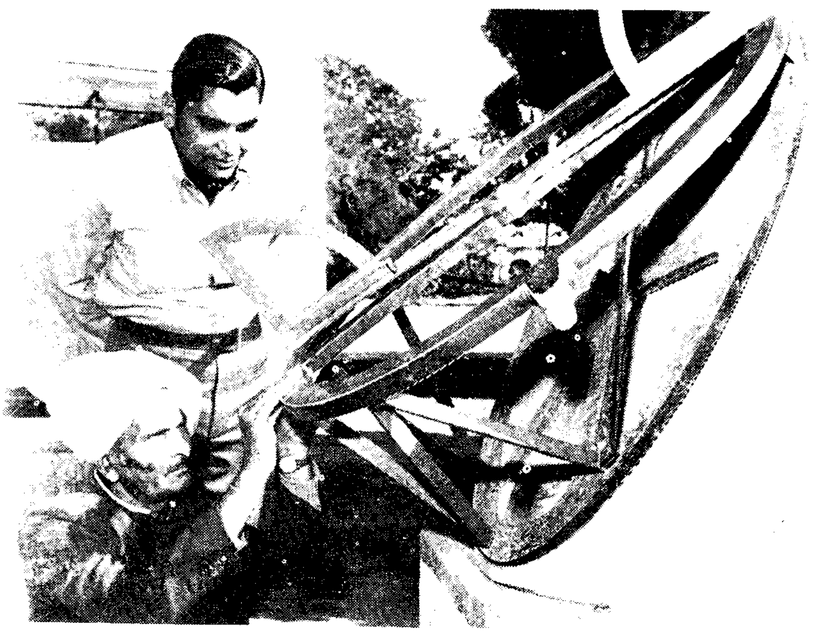
The stone circle is graduated in 60 'ghatika' markings, equivalent to 24 hours and further sub-divided in minutes and seconds of arc. The metal frame is graduated in 360 degrees along with 12 Zodiac signs.

There is a separate metal attachment ('Nalika' or brass tube), available at the observatory office, which is fitted in the hole at the centre of the ecliptic frame, at the time of observation.

The stars and planets are observed through this device attached to the ecliptic frame which can be rotated with the help of handles, provided for the purpose, as and when required.



The Ecliptic Instrument

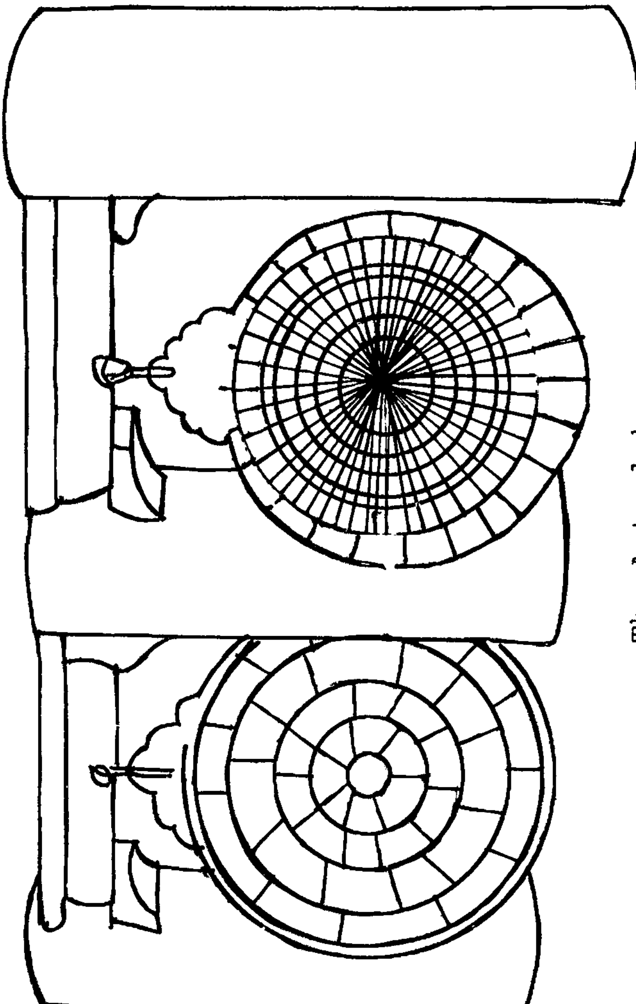


Pandit Kalyan Dutt Sharma, the traditional Astronomer-Astrologer of Jaipur, observing with the Ecliptic Instrument. Over looking is the author.

As the metal frames and the stone base put together make an angle equivalent to the double of the obliquity of ecliptic (47 degrees), this efficient instrument can be used at any time of day or night, to determine the stars' and planets' distance (latitude) from the equinox (equator) and distance (longitude) from the ecliptic.

6 THE ASTROLABE

AN ancient type of astro-calculator, the YANTRA RAJ; literally the king of all instruments, fascinated the Maharaja to the extent of writing two volumes on the principles and utility of this metal device, entitled 'YANTRA RAJ KARIKA' which is one of the proud possessions of the City Palace Museum, Jaipur. This vertically hanging instrument is virtually a celestial map, neatly engraved on a huge metal disc of over 2 meter diameter. The hole at its centre is the Pole Star 27 degrees below this point, a prominent line represents the Local Horizon. Then there is the Local Meridian Line drawn North-South and other meridian parallels. Another set of line is drawn parallel to the Horizon. Celestial Equator, Tropics of Cancer and Capricorn, Prime Vertical, Ecliptic Circle and hour angles are distinctly drawn on the dial The outermost circle is graduated in 60 'ghatikas' (equivalent to 24 hours) of 6 fractions each. The inner circle bears 360 degree markings, each of 6 sub-divisions. The names of the 27 Constellations of prominent stars like



The Astrolabe

Rohini (Tauri), Lubdhak (Canis Majoris), Samudra Pakshi (Ceti), Pushya (Cancri), Chitra (Virginis) etc.are also depicted to make it a perfect map of the sky.

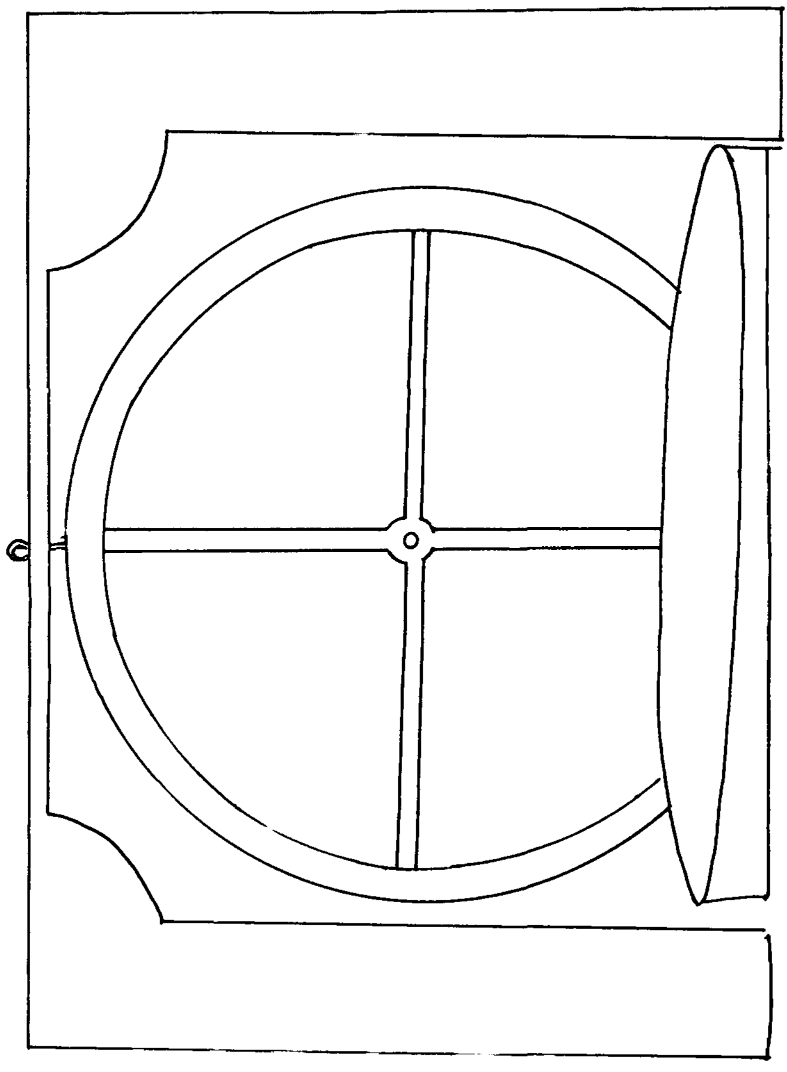
There is a separate metal attachment - representing the Ecliptic Circle-fixed at the central hole (Pole Star) which can be rotated at the time of observation. The Ecliptic Attachment bears 12 Zodiac signs graduated at a distance of 30° from each other.

A metal tube is then fixed at the centre to observe the stars and planets through it. Its position on the well-graduated ecliptic circle, outer and inner circles, indicates Zenith Distance, Declination, Latitude, Longitude and Altitude of heavenly bodies. The Ascendant,(Lagna), the 4th, 7th and 10th Houses of the Zodiac Signs etc can also be determined for astrological calculations with the help of the YANTRA RAJ.

7. THE ALTITUDE INSTRUMENT

THE 'UNNATANSHA YANTRA' is another important metal instrument which is situated in the north-eastern corner of this observatory.

It is a big metal circle of about five meter diameter hanging in vertical plane on a massive masonary support. The suspension of this heavy metal circle in a hollow space below, allows it to rotate in the vertical plane for the purpose of celestial observations. The entire circle of 4 equal segments of 90 degrees each, is thus, graduated in



The Altitude Instrument

360 degrees, each of 10 parts. There is a hole at the centre of the Altitude Instrument where a pointer is fixed at the time of observation.

The 'Yantra' is used to determine the celestial altitude of heavenly bodies. The method of observation is simple. The observer has to stand by the circular device placed in front of the celestial object under observation. Then he places his eye on the graduated circle at such a point that the particular heavenly body is seen through the medium of the pointer fixed at the centre. The position of his eye on the well-marked circle denotes the celestial altitude of a star or planet thus observed. Some steps are also provided at the lower portions of the pit where the observer can sit to observe the heavenly bodies of higher altitude in the same manner as explained above at any time during day or night.

8. THE MERIDINAL-WALL INSTRUMENT

THE 'DAKSHINOVRITTI BHITTI YANTRA' is situated in the north-eastern corner of this observatory. The Meridinal Wall is absolutely vertical and is built in the plane of local meridian - exact north-south. The eastern and western faces of this meridinal wall comprise two meridinal instruments which have somewhat different shapes but are meant for the same observations of the heavenly objects as and when they cross the local meridian.

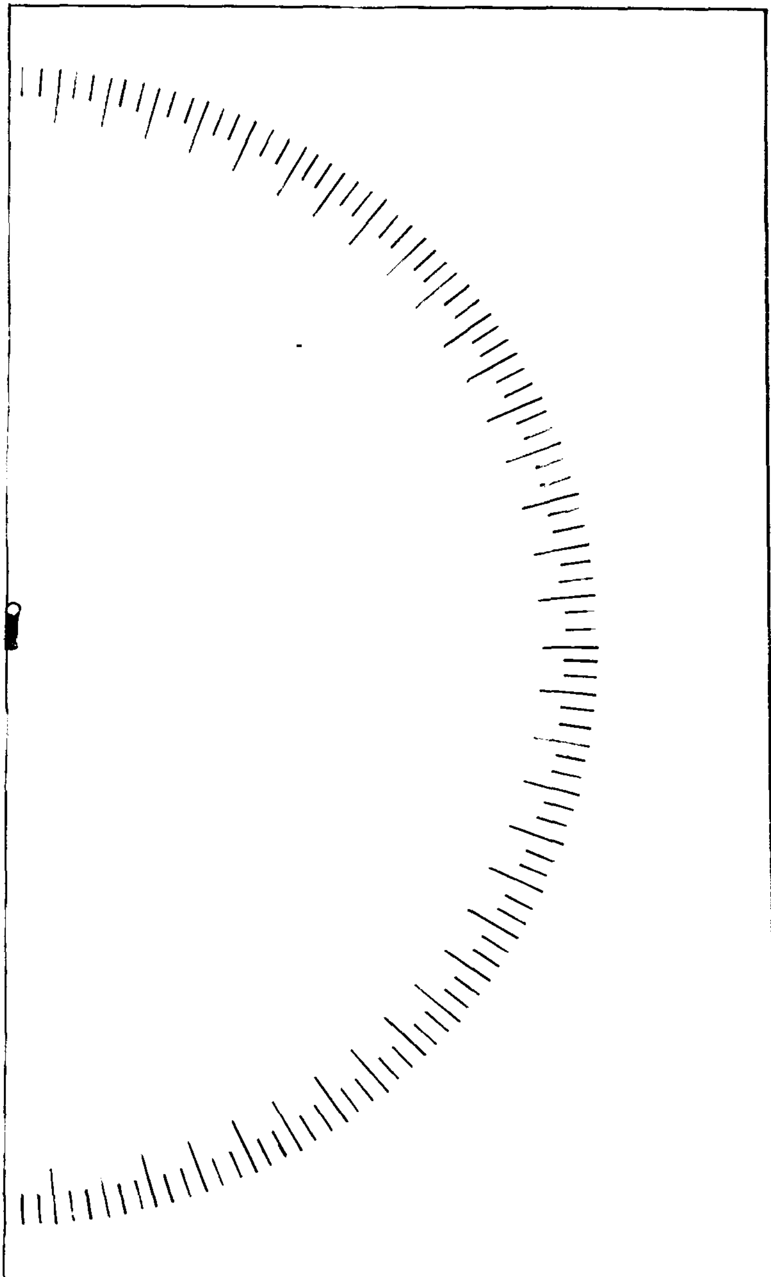
8-A. THE WESTERN WALL INSTRUMENT

THE western face of the Meridinal Wall consists of an inverted semi-circle of marble neatly graduated in 180 degrees. An iron peg is provided at the centre of this semi-circle towards the top of the wall. The shadow of the iron peg falls on the graduated semi-circle below, when the sun crosses the local meridian at 12 O' clock Local Time. No shadow is involved during the night observations. Hence a thread is tied to the peg and the observer stretches it on the graduated scale to align it to the heavenly body at its meridian pass time. Steps are provided all along the semi-circle so that an observer can sit and observe the celestial spheres when they are on the local meridian by keeping his eye on the graduated semi-circle. The place of the eye is taken in account for similar calculations at night.

8-B THE EASTERN WALL INSTRUMENT

THE eastern face of the Meridinal Wall consists of two quadrants of 90 degrees each. They both intersect each other at an angle of 60 degrees. Hence, they may be called as Sextants also. These marble quadrants are also inlaid in the masonary wall and are beautifully graduated by lead in degrees and their decimals.

On top of both the quadrants, two iron pegs are provided for the purpose of observations and calculations. The



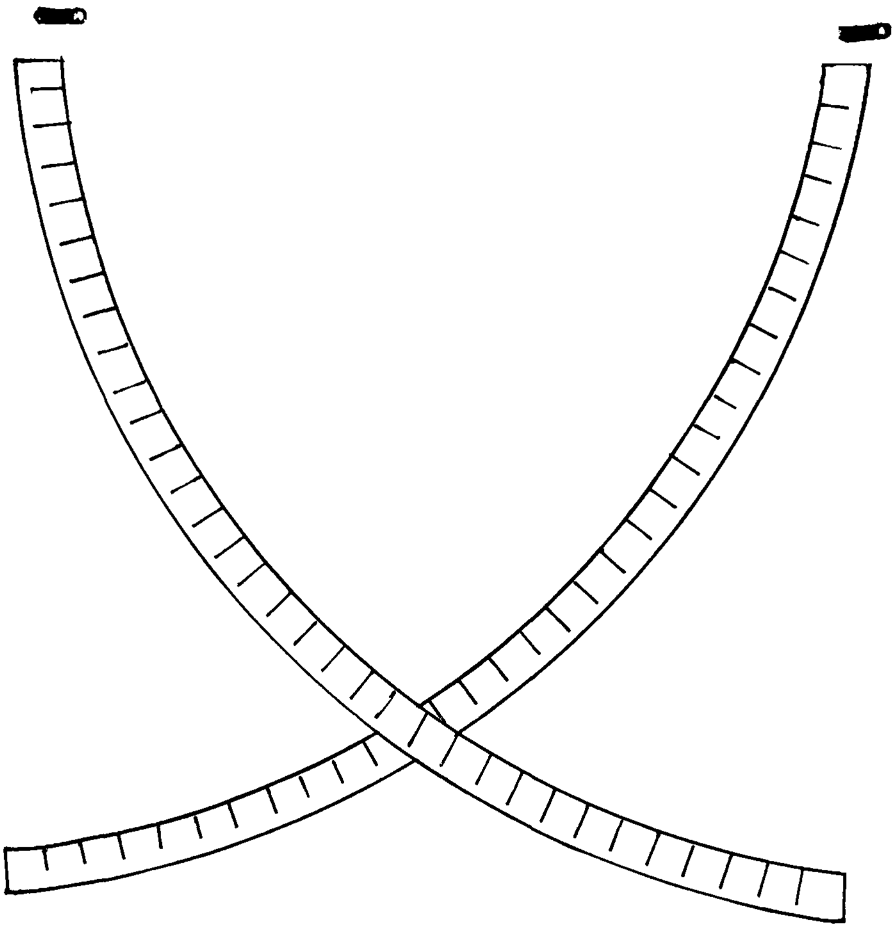
The Western Meridinal Wall Instrument

shadow of the peg falls on the graduated arc below when the sun crosses the local meridian at mid-day (local time). The threads are tied to these pegs for aligning the heavenly bodies at their meridian pass time with the eye of the observer placed on the graduated arc for observations during night.

It is a multipurpose instrument and indicates Zenith Distance, Altitude, Meridian Pass Time, Declination, Rising and Setting time of stars and planets, length of day and night etc. As already mentioned, this instrument is used both during day and night

The shadow of the iron pointer falls on the graduated arc at mid-day and indicates the Zenith Distance from 90 degrees, the Altitude of the sun is derived. The Declination is easily arrived at by adding or subtracting the latitude of the place of observation (27 degrees in case of Jaipur) from the Zenith Distance. The Declination of Sun is added to (N) or subtracted(S) from the Zenith Distance to verify the Latitude of Jaipur (26 degrees 56 minutes 27 seconds or 27 degrees).

Further, the sun-set time is derived by deducting the local sun-rise time from 12 hours. By deducting the sun-rise time from the sun-set time, the length of day is easily calculated. If the latitude of the place is multiplied by the Declination and then divided by 5, the result would denote

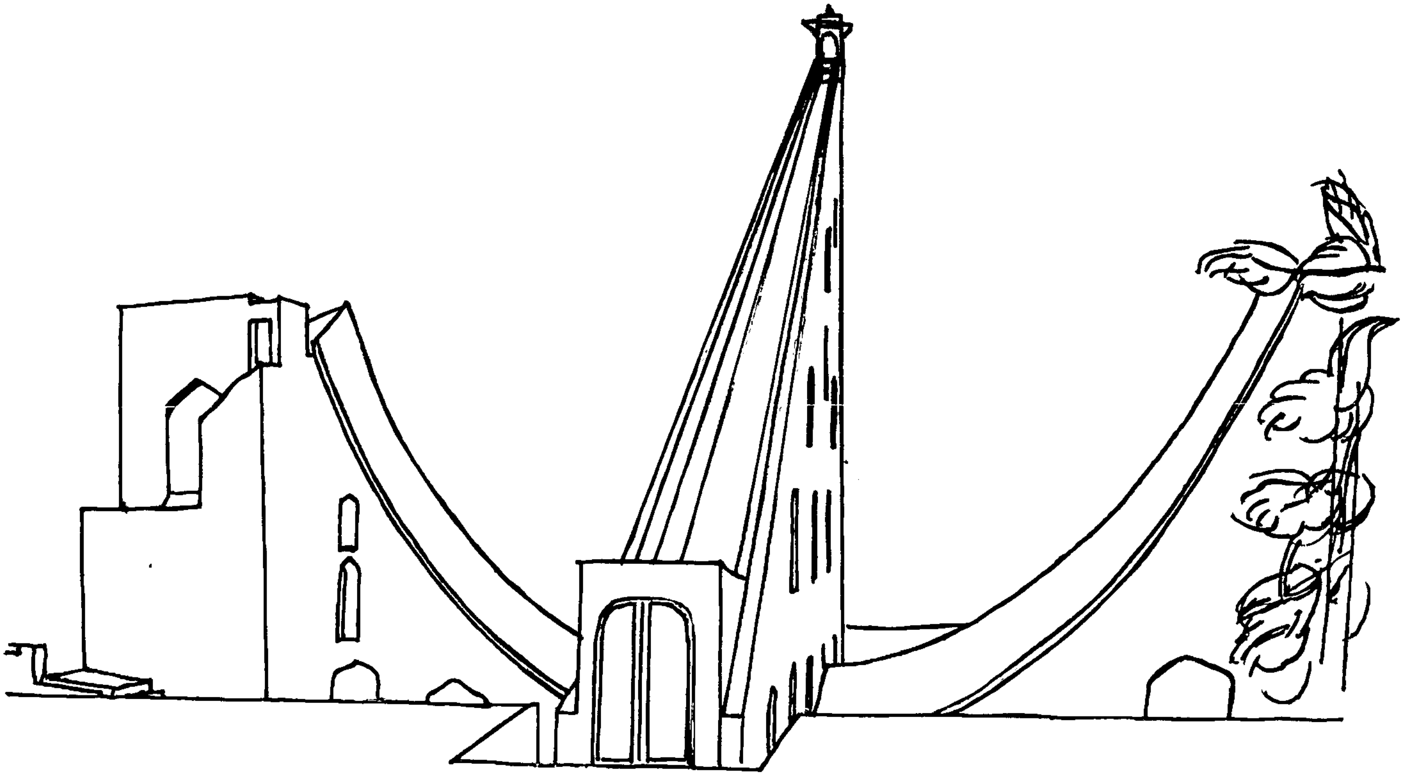


The Eastern Meridinal Wall Instrument

the Ascensional Difference. If the Zenith Distance of a heavenly object is more than 27 degrees, it would be in the Southern Hemisphere, and if less than 27 degrees, the same would be in the Northern Hemisphere. Similar formula is used to derive the same results with regard to planets during night.

9. THE GIANT EQUATORIAL SUN-DIAL

THIS gigantic BRIHAT SAMRAT YANTRA is identical in theory and function to the LAGHU SAMRAT YANTRA, described earlier (No.1), but is ten times bigger in proportions which consequently makes it ten times more precise than its smaller version. The dimensions of this Titanic Sun-Dial are interesting to know. The base of this right-angled triangle is 44 meters long whereas its hypotenuse making an angle of 27 degrees rises to the height of 27 meters The lofty triangle is flanked by two king-size quadrants of 15 meter radius which are graduated in hours, minutes and seconds, where the shadow of the gnomon travels about 4 meters during one hour. The same shadow moves 6 centimeters indicating each minute which is further sub-divided by thirty fractions, each standing for an incredible precision of 2 seconds. As already mentioned, this Giant Equatorial Sun-Dial indicates the Local Time, Meridian Pass Time, Zenith Distance, Declination and Altitude of the celestial spheres by the shadow of the



The Giant Equatorial Sun-Dial

hypotenuse of the triangle, which serves as a gnomon for this Sun-Dial. During night, the observer has to sit by the graduated quadrants and place his eye on their edge to observe the heavenly bodies through the hypotenuse for the above calculations. The place of eye on the quadrant is counted for similar readings of celestial positions.

This Yantra boasts of being the biggest and the most precise Sun-Dial in the world and deserves its mention in the Guinesse book of World Records.

9-A. THE WEATHER FORECAST BELVEDERE

The Giant Equatorial Dial as described above, is crowned by a beautiful belvedere (chhatri) which is still used for forecasting the advent of monsoon, storms, droughts and famines etc. Such weather forecasts are based on the direction of the wind which is observed on top of the Samrat Yantra on Ashadh-Purnima, or Guru Purnima, which is the full moon day in the Hindu month of Ashadh(June-July).

The Brahmin-astrologers and Pandit astronomers assemble on top of the Samrat Yantra at the time of sunset. A thin muslin flag is hoisted to determine the exact direction of wind and weather is forecast accordingly. Easterly breeze indicates good rains and good crops whereas southern wind means scarcity of monsoon, resulting in famines. Heavy

rains and floods are caused by westerly wind and northern breeze brings in plenty of rains and abundant crops. This weather forecast ceremony is widely attended by the Brahmin scholars and astronomers, who are traditionally dressed and throng the "chhatri" on top of the Brihat Samrat Yantra The event is described by the newspapers also.

9-B. THE SEXTANT INSTRUMENTS

THE sextants are located in two chambers built on either side of the "Brihat Samrat Yantra" described above Only one chamber towards west is open on request for visitors and observers now a days. The "SHASHTHANSHA YANTRA" consists of two arcs of sixty degrees each, made adjacent to the eastern and western wall of the dark room. The arcs are of sixty degree each and lie north-south in the plane of local meridian. This sextant instrument is used at mid-day (Local Time) when the sun crosses the Local Meridian and its rays fall on the graduated arcs through two tiny orifices provided in the roof for the purpose.

The arcs have two scales. There are degree markings near the wall for direct observation of Declination of the Sun at noon and second scale is used for observing the Zenith Distance of the sun. At noon, the rays of the sun fall through the pin-holes made in the roof above, in the size of a tennis ball on the graduated arcs for a minute or two.

With the help of the above mentioned two scales, the Zenith Distance, Altitude, Declination etc of the sun are directly determined at mid-day when it crosses the Local Meridian.

9-C. THE EQUATORIAL DIAL-PLAN

THE plan of constructing and graduating the huge quadrants of the Giant Equatorial Dial is located on a large platform north-west of the Giant Equatorial Sun-Dial. The red sand-stone circle of about 15 meter diameter is neatly graduated in hours, minutes and seconds, which served as the blueprint for graduating the gigantic quadrants of the Equatorial Sun-Dial later To protect this 'blue-print' in stone, the authorities have made a metal railing all around this platform

10. THE ZODIAC INSTRUMENTS

KNOWN as 'RASHI YANTRAS' or the 'RASHIVALAYA', it is a group of 12 instruments representing all the 12 Zodiac Signs, situated on a ractangular platform near the southern wall of the observatory.

They look like smaller versions of the Equatorial Sun-Dial, but are quite different technically The triangular gnomon of the Equatorial Dial points towards the North Pole whereas the gnomons of the Zodiac Instruments indicate the Pole of the Ecliptic at the time of observation. Unlike the Pole, the Pole of the Ecliptic is not a fixed point but

is defined as a circle of 23°27' radius around the Pole.

Secondly, the quadrants of the former lie in the plane of the Equator, whereas those of the Zodiacs lie in the plane of the Ecliptic.

The angular construction of the gnomons of the Rashi Yantras is different from each other due to the different situation of each Zodiac Sign from the Pole of the Ecliptic. The local latitude and the declination of each Zodiac sign at its Meridian Pass Time are taken into consideration for the construction of the gnomons of these Zodiac Instruments.

The quadrants of the Rashi-Yantras are graduated in sines and degrees for determin ing the celestial longitudes and their gnomons bear the tangent degree markings for observing the celestial latitudes north or south of the Ecliptic. The following table indicates the graduations of degrees on the quadrants of each Zodiac showing a difference of 180 degrees as two quadrants make a semi-circle.

ZODIAC SIGNS	GRADUATIONS OF DEGREES ON THE QUADRANTS	
	EAST	WEST
1. Aries	281½	101½
2. Taurus	305½	125½
3. Gemini	331½	151½
4. Cancer	0	180
5. Leo	28½	208½
6. Virgo	54½	234½

7.	Libra	78½	258½
8.	Scorpio	104½	284½
9.	Sagittarius	137	317
10	Capricorn	180	0
11	Aquarius	223	43
12.	Pisces	255½	75½

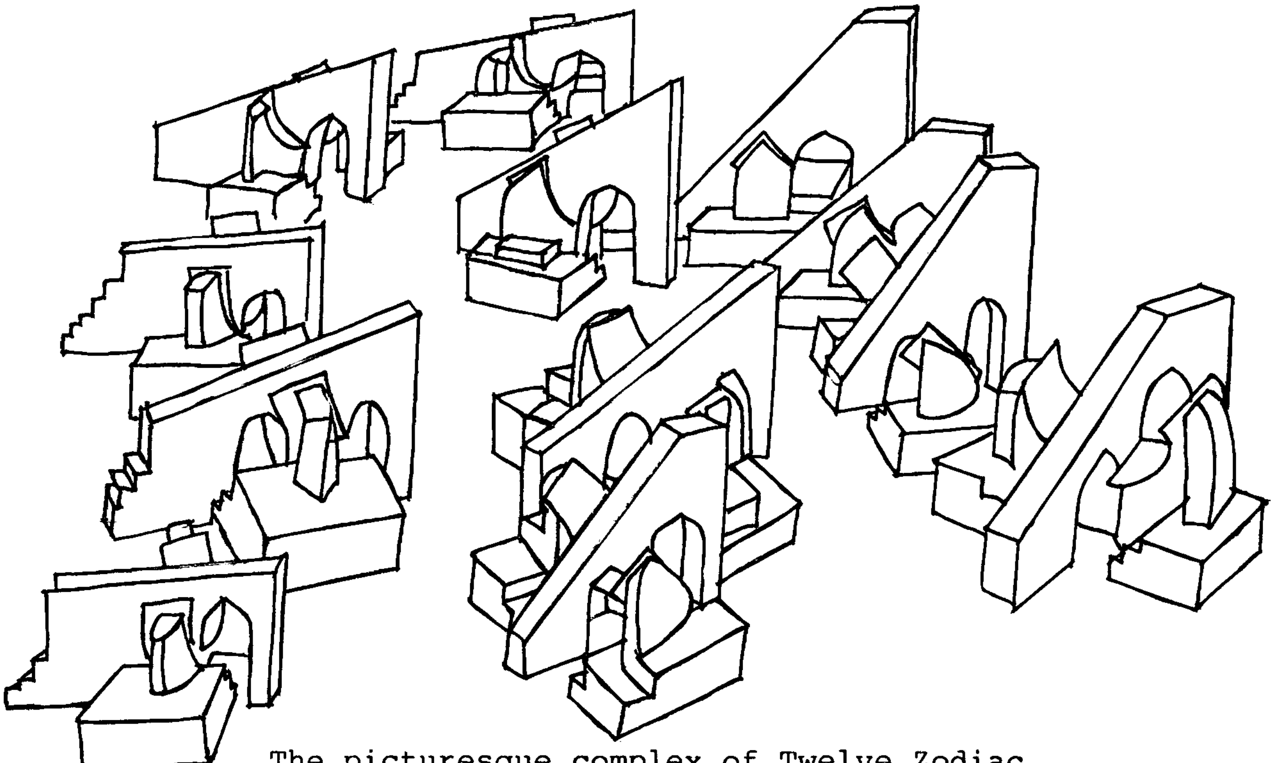
Signs		Longitude of signs in degree	Azimuth of gnomons Deg. min.	Altitude of gnomons Deg. min.
1.	Aries	0	-25.56	24.32
2.	Taurus	30	-21.17	14.25
3.	Gemini	60	-12.19	6.36
4.	Cancer	90	0.0	3.28
5.	Leo	120	12.19	6 35
6.	Virgo	150	21.17	14.25
7.	Libra	180	25.56	24.32
8.	Scorpio	210	25.37	35.33
9.	Sagi-ttarius	240	17.40	45.42
10	Capricorn	270	0.0	50 22
11.	Aquarius	300	-17.40	45 42
12.	Pisces	330	-25.37	35.33

These curious looking instruments are used for direct observation of the latitudes and longitudes of the sun and planets. Each instrument can be used almost every two hours when the corresponding Zodiac sign culminates on the local meridian. The astronomical data thus collected are used to compile the astronomical tables, ephemeris and almanacs which are later used for various astronomical and astrological calculations.

To determine the celestial latitude and longitude of a particular heavenly body with the help of these instruments, the observer has to find out with the help of the Jai Prakash Yantra or the mathematical calculation, the exact time when a particular Zodiac sign culminates on the Local Meridian. At that time, the corresponding Zodiac Instrument is used for observing the heavenly body to find its celestial positions.

During day, the shadow of the gnomon on the graduated quadrant would indicate the longitude of the Sun and its latitude is always zero as it always moves in the ecliptic. At night, the particular planet is aligned with the help of a thread or a tube, both ends of which are kept on the edges of the gnomon and the quadrant. The observer has to sit near the quadrants where the steps are provided for the purpose and achieve this alignment by keeping his eye on the edge of the graduated quadrant.

The place of his eye would indicate the planet's longitude whereas the other end of the thread or tube on the graduated hypotenuse, its latitude.



The picturesque complex of Twelve Zodiac Instruments

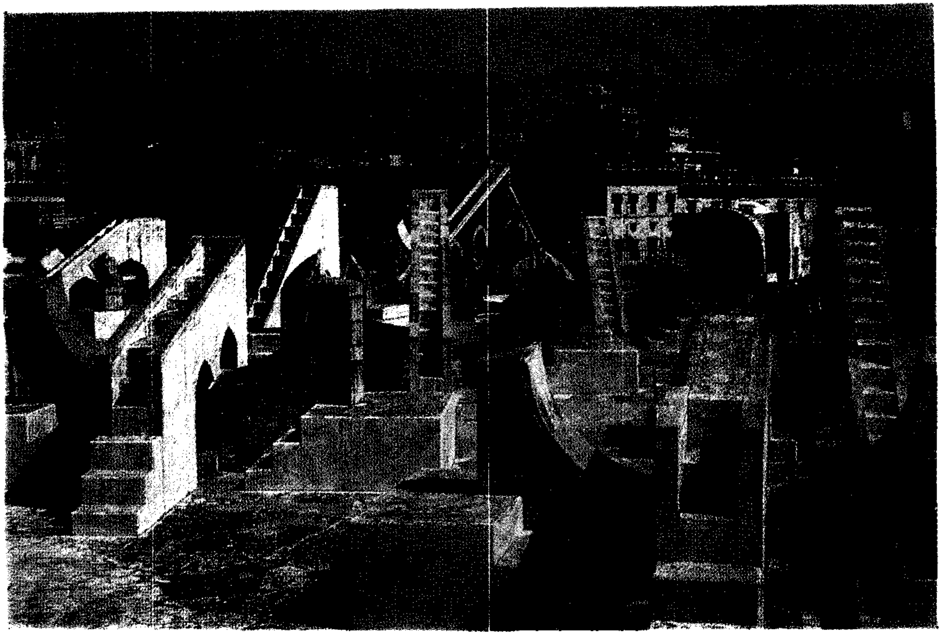
THE ZODIAC ASTROLOGY

	Date of Birth	Zodiac Signs	Fortunate Stones	Lucky Colours	Lucy Day
1.	March 21 to April 20	Aries the Ram	Amethyst, Diamond	Red,Crimson, Scarlet	Tuesday
2.	April 21 to May 20	Taurus the Bull	Sapphire, Cat's eye	Blue, Sea green	Friday
3.	May 21 to June 21	Gemini, the Twins	Emerald, Alexanderite	Yellow	Saturday
4.	June 22 to July 22	Cancer the Crab	Pearl, Moonstone	Cream, Green	Monday
5.	July 23 to August 22	Leo the Lion	Ruby,Star Ruby	Gold & Orange	Sunday
6.	August 23 to September 22	Virgo,the Virgin	Star sapphire Sardonyx, Peridot	Grey	Wednesday
7.	Sept.23 to Oct.22	Libra,the Scales	Chrysolite, Opal,Lapis	Pastel,Blue, Green	Friday
8.	Oct.23 to Nov.21	Scorpio,the Scorpion	Topaz	Dark red, Crimson	Tuesday
9.	Nov.22 to Dec.21	Sagittarius, the Archer	Turquoise	Purple, Lilac	Thursday
10.	Dec.22 to Jan.20	Capricorn, the Seagoat	Zircon,Onyx	Dark Green, Black,Grey	Saturday
11.	Jan.21 to Feb.19	Aquarius, the Water Bearer	Garnet, Amethyst	Pastel shades of Blue, Green	Wednesday
12.	Feb.20 to March 20	Pisces,the Fish	Aquamarine, Bloodstone	Violet,Mauve, Lavender	Friday

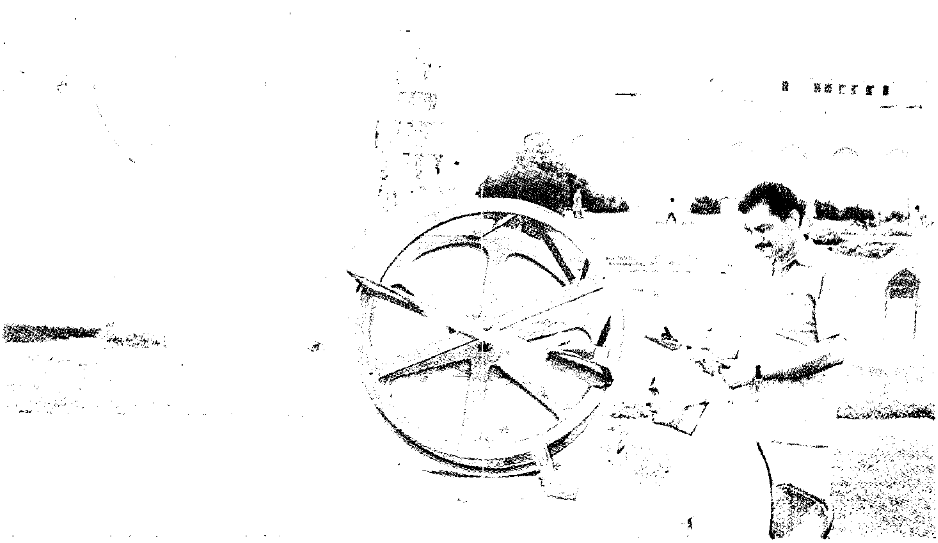
11 THE ARMILLARY SPHERE INSTRUMENT

INVENTED by Maharaja Sawai Jai Singh, this kaleidoscopic structure is known as 'JAI PRAKASH YANTRA' - literally meaning the Light of Jai. Lying between the Zodiac Instruments and the Southern Sun-Dial, the Armillary Sphere consists of two hemispherical marble bowls sunk in rectangular sand-stone platform. The concave hemispheres of about 5.5 meter diameter represent the celestial sphere turned upside down. The rim of the bowls represent the horizon which is neatly graduated in 360 degrees. The central point at the bottom represents the zenith through which the Local Meridian Circle is drawn North-South Another prominent line drawn east-west is the Celestial Equator, on both sides of which two lines of Tropics of Cancer and Capricorn are also drawn. Then there are meridian parallels (azimuth circles) and horizontal parallels (altitude circles). Besides, twelve zodiac circles are drawn from the celestial equator at a difference of their declination A cross-section of metal wires holding a metal ring at the centre is fixed over the four directions over the Yantra in such a way that the metal ring stays exactly above the central point (zenith).

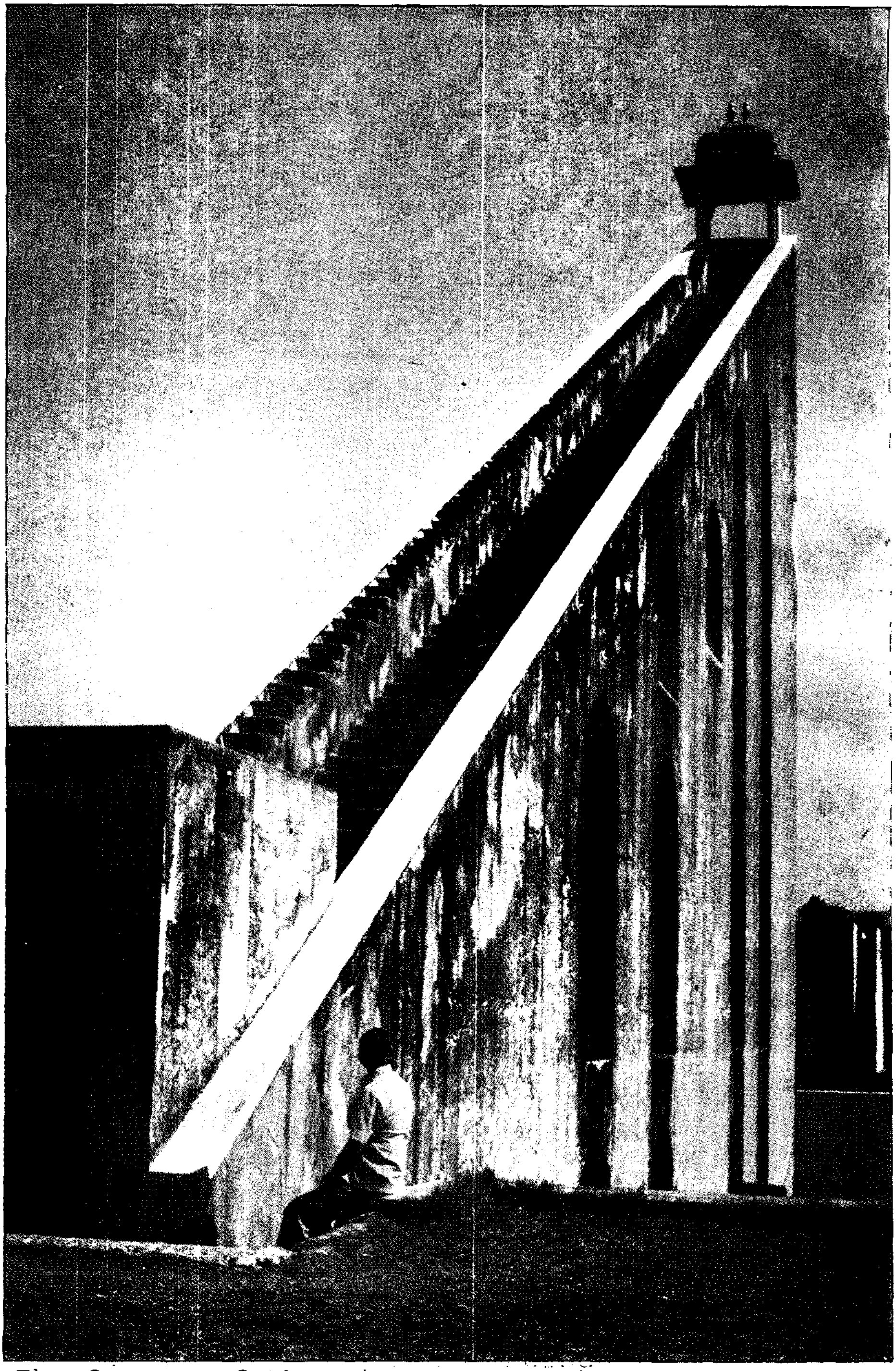
These two identical looking instruments are complementary to each other and are made side by side. Each marble slab stands for one hour observations. The space in one is filled by marble scale in the other, and thus, they both work on alternate hours



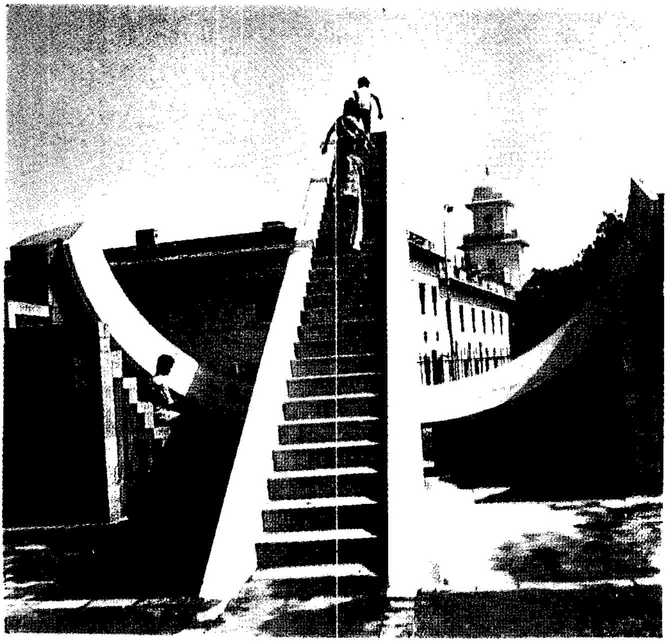
The Jaipur Observatory



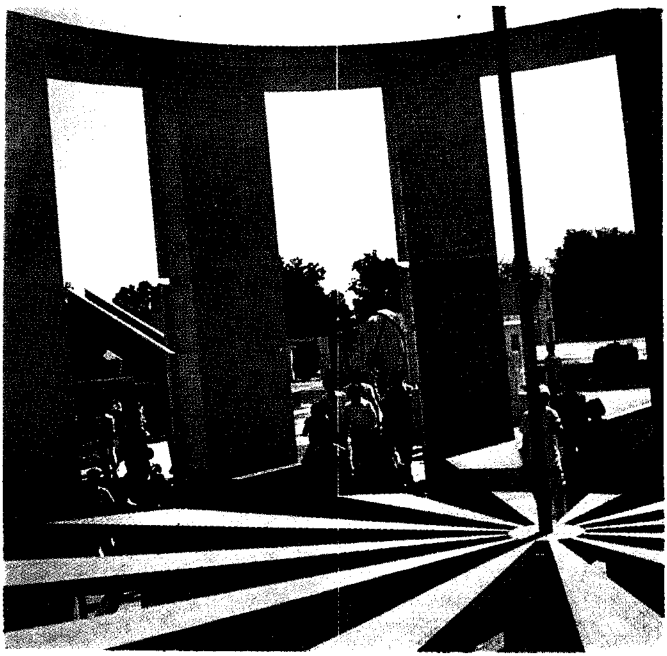
Traditional astronomer, Pandit Kalyan Dutt Sharma, observing with the author, at the Ecliptic Instrument (Jaipur)



The Gnomon of the Giant Equatorial Sun-Dial with
the Observatory Tower (Belvedere) (Jaipur)



The Small Equatorial
Sun-Dial (Jaipur)



The Interior of the
Altitude Instrument (Jaipur)


The Jaipur Observatory - A Panoramic View.


The Varanasi Observatory

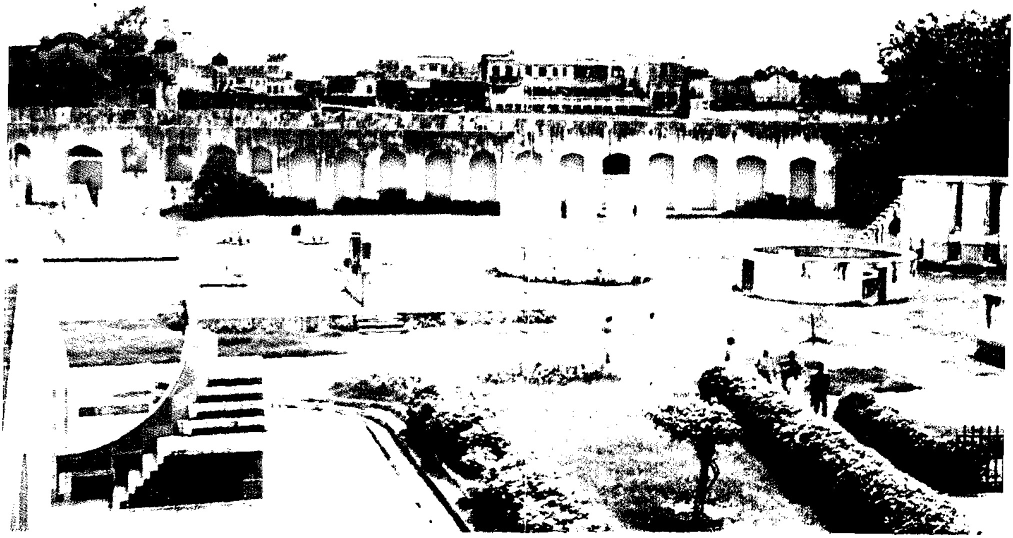
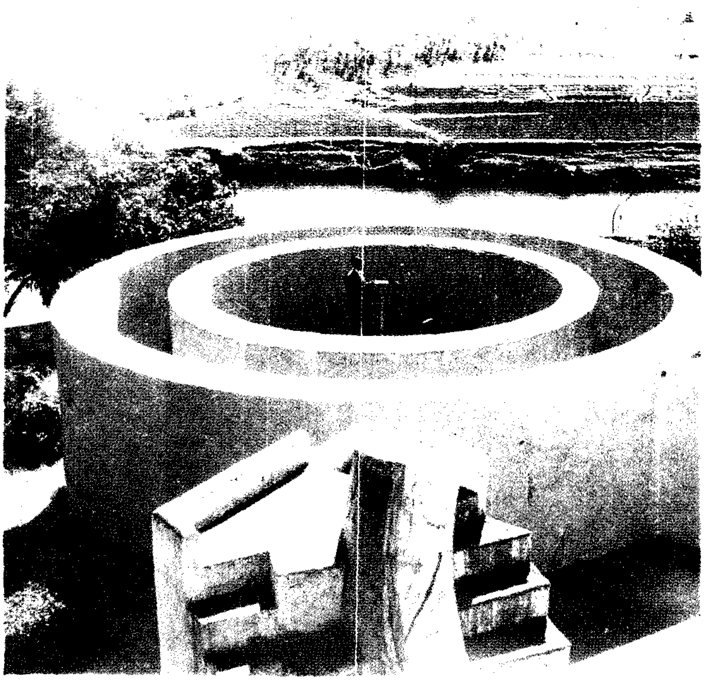
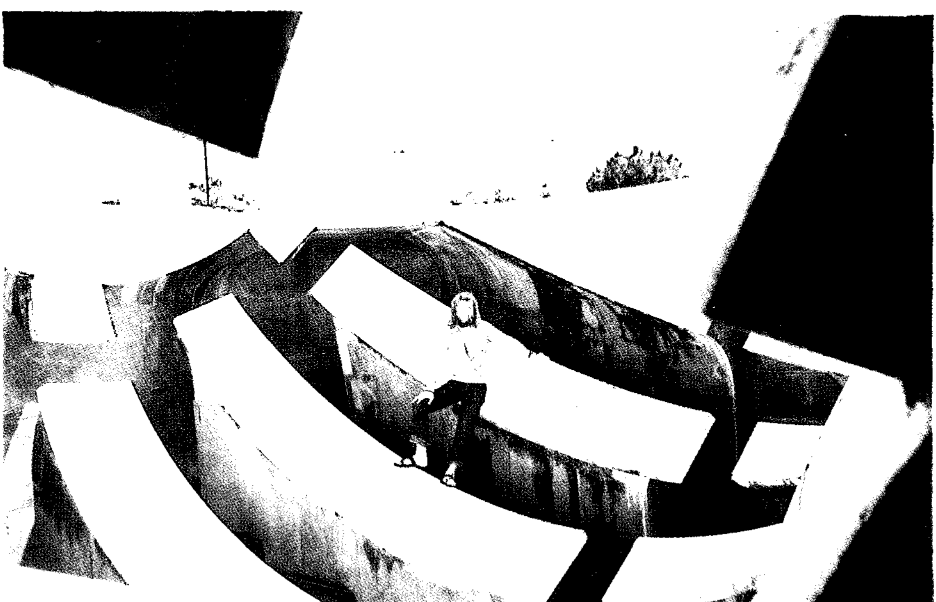


Photo : Santosh

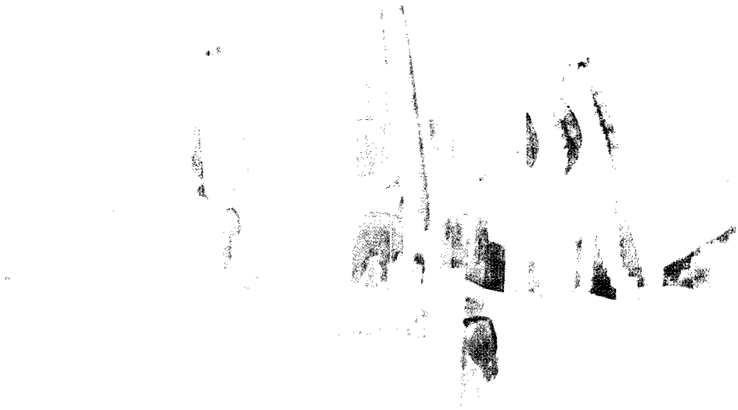


The Ujjain Observatory

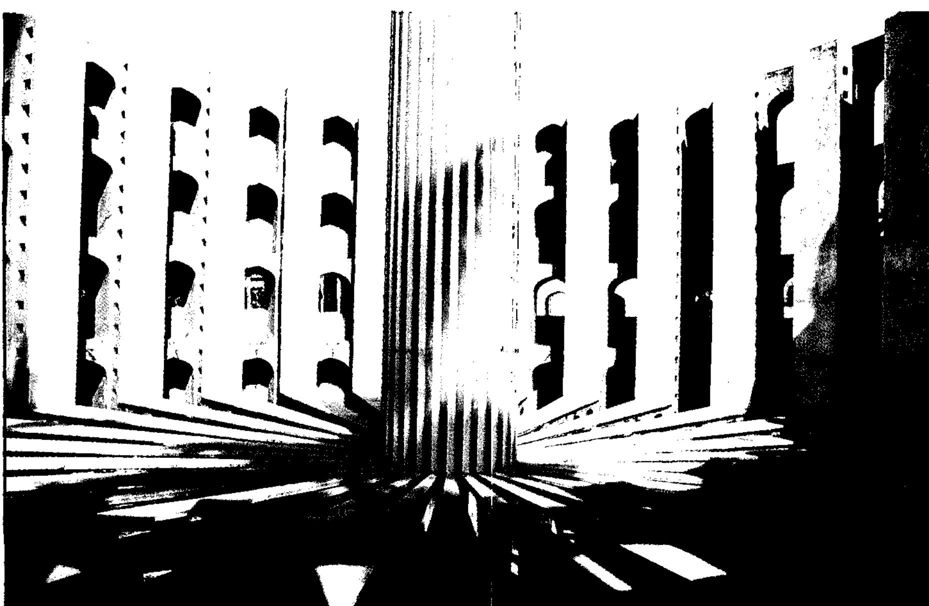
The author explaining the Hemispherical Sun-Dial (Jaipur)



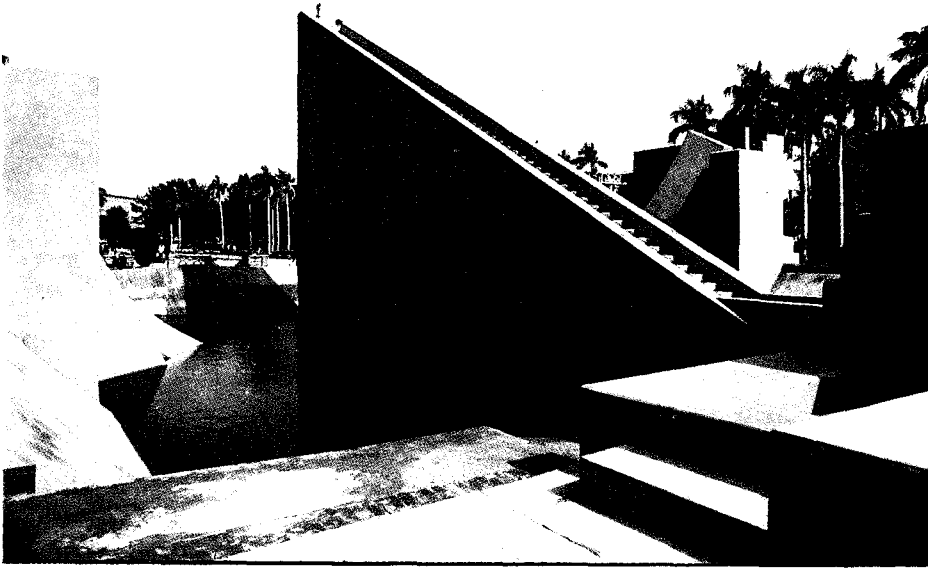
The Interior of the Armillary Sphere (Jaipur)



The Composite Instrument (Delhi)
Painting : Monica SAITO

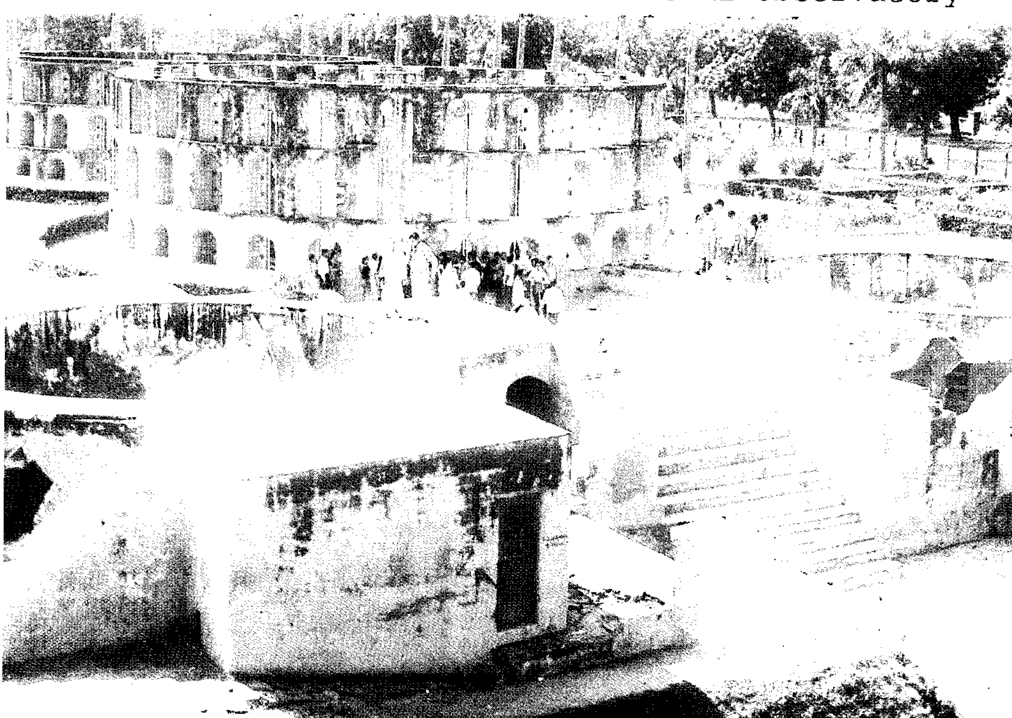


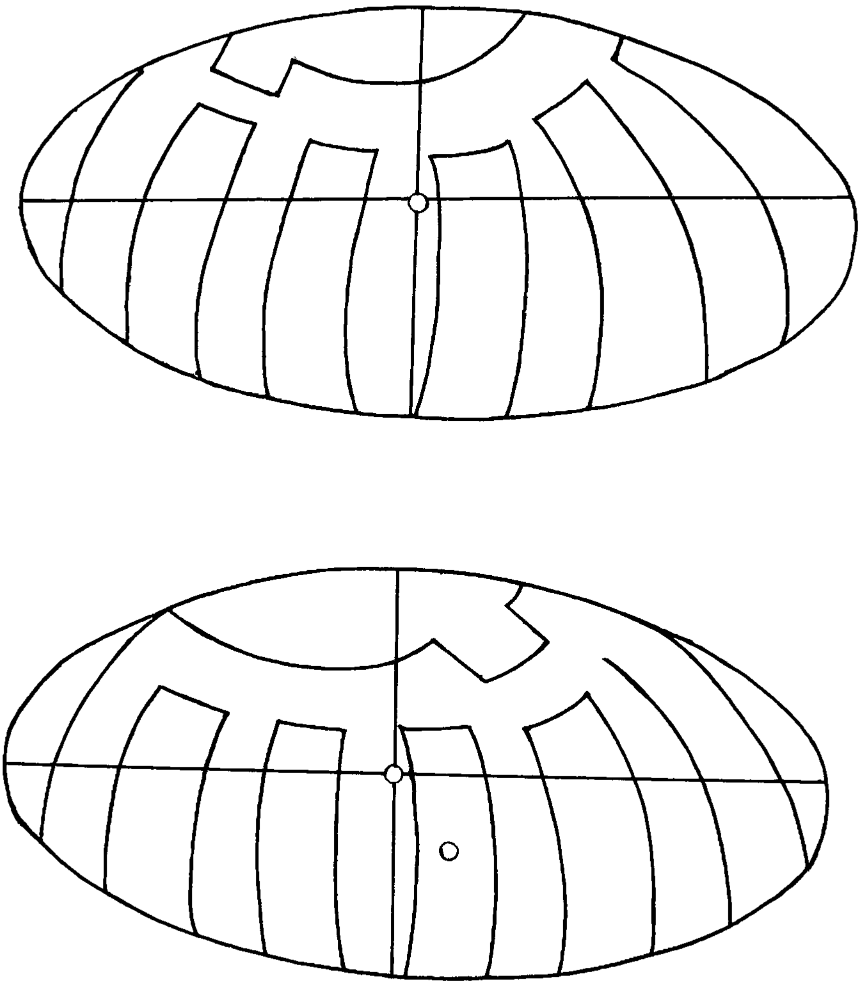
The Interior of the Altitude Instrument (Delhi)



The Big Equatorial Sun-Dial (Delhi)

The Delhi Observatory





The Armillary Sphere Instrument

The method of observation with the 'Jai Prakash' is interesting. During day, the shadow of the sun falls through the metal ring on the graduated surface below. The distance between the centre of the shadow spot and the above mentioned lines viz., Horizon, Local Meridian, Celestial Equator, Tropics, Zenith etc. would indicate Local Time, Altitude, Azimuth, Meridian Pass Time, Zenith Distance and Declination of the Sun. By observing the same shadow in a particular Zodiac Circle, one could determine Sun's Longitude and the 10th House of the Zodiac used for casting horoscopes etc.

It is fascinating to use the Yantra for celestial observations during night. The observer has to go down the marble cavity, sit between the slabs, or lie down on them to observe the celestial object through the metal ring in such a way that the particular heavenly body, the hole of the ring and the eye of the observer, make a straight line. The position of the observer's eye on the scale would indicate the above mentioned measurements and placements of the celestial spheres during night.

12. THE HEMISPHERICAL BOWL INSTRUMENTS

THESE instruments are known as 'KAPALI YANTRAS' which are located on a masonary platform in the western half of the observatory Like the 'Jai Prakash', the 'Kapali Yantras' consist of marble bowls representing the celestial spheres.

THE EASTERN KAPALI

It represents the half of the celestial sphere. Its rim represents horizon. There are various lines drawn criss-crossing its entire surface. This Yantra is not used for any observations as such but is utilised for solving the astronomical problems graphically.

THE WESTERN KAPALI

The western hemispherical cavity is the real observational device. There is a labyrinth of semi-circular lines drawn all over the surface of this marble bowl which is sunk in a masonary platform. It is like the Jai Prakash Yantra in graduations and functions. Its rim represents the horizon neatly bearing 360 degree markings. Then there are 15 horizontally drawn altitude circles at a distance of 6 degrees from each other. The Local Meridian Line is prominently drawn north-south which goes through the centre of the 'Kapali'. There are 30 meridian parallels drawn on either side of the Meridian Circle. The Celestial Equator is also a bold line drawn east west which goes along six parallel lines representing all the Zodiac signs. Each line stands for two Zodiac signs whose names are distinctly inscribed on them. The Ecliptic Circle of 23 degrees 27 minutes radius is drawn around the Pole which is marked by Central Point of a small circle below the horizontal rim on the southern portion of the Kapali. A cross-section of metal wires holding a ring exactly over the centre of the Kapali is

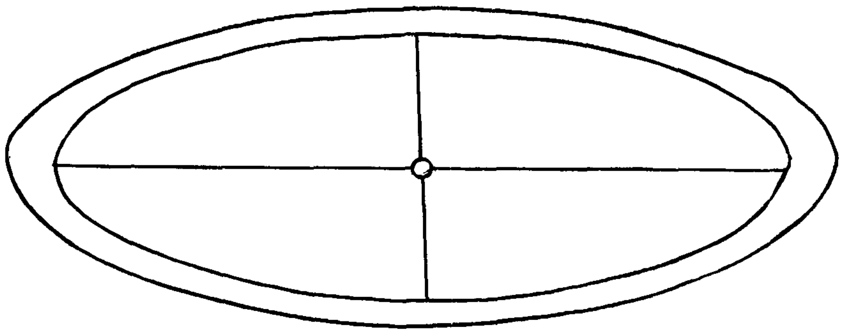
fastened on the rim at four points indicating exact north, south, east and west. The shadow of the ring falls on the graduated interior of the Kapali which is measured from different celestial lines as mentioned above to determine the Local Time, Azimuth, Altitude, Meridian Pass Time, Declination of the sun etc. The shadow is observed in relation to the Zodiac lines to determine the longitude of the sun.

During night, the observer has to slide down inside the Kapali to lie down to observe the planets and stars through the hole of the ring to derive the above mentioned measurements of the heavenly bodies, particularly the longitude of planets and the tropical ascendant of planets and stars which are very useful for casting the horoscopes and making astrological forecasts.

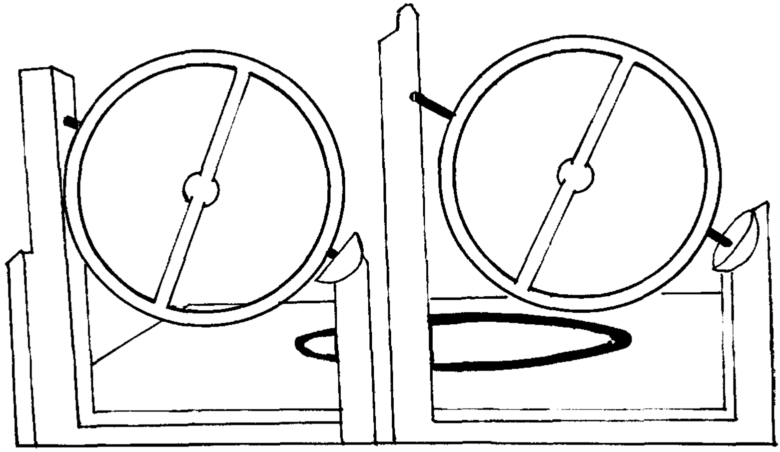
It may be noted that the rising time of each zodiac sign on the horizon is known as the beginning time of the tropical ascendants which the Brahmin astrologers usually calculate mathematically. For astrological calculations, such data are of vital importance which the Pandit-astrologers can directly observe with the help of the sophisticated Kapali.

13. THE CIRCULAR INSTRUMENTS

THERE are two identical 'CHAKRA YANTRAS' framed on stone pillars located between the Eastern and Western Kapali Yantra. Made of an alloy of seven metals, each Yantra



The Hemispherical Bowl Instrument



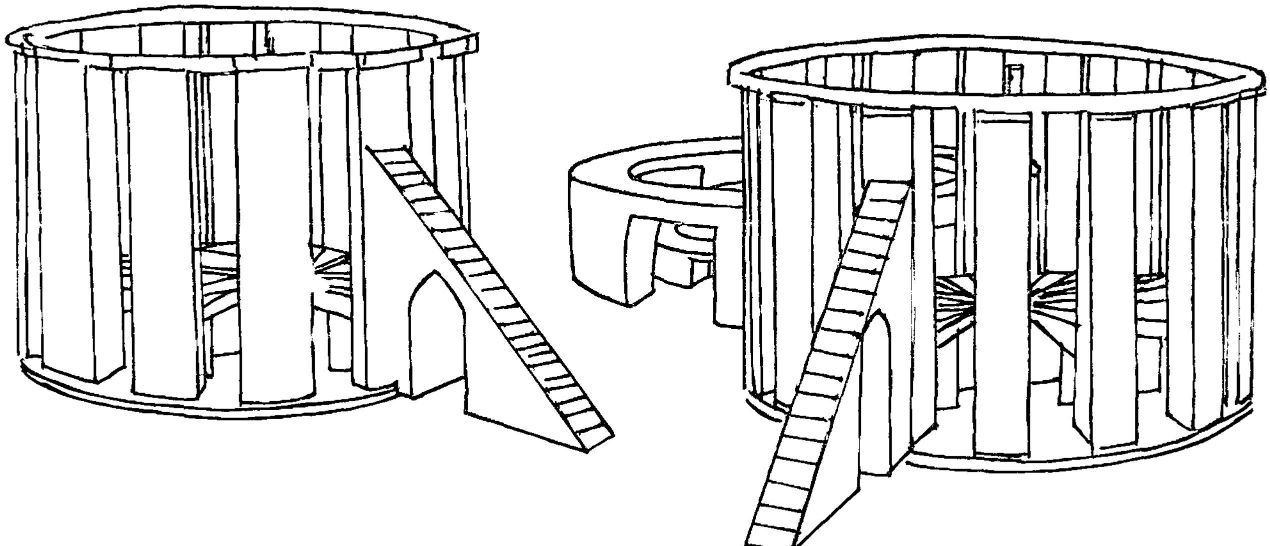
The Circular Instruments

consists of a metal circle bearing 360 degree graduations. The metal diameter has a hole at its centre where a brass tube is attached at the time of celestial observations. The metal circles are free to move on their masonary stand about a diameter parallel to the celestial equator or the earth's axis ($23\frac{1}{2}$ degrees). A metal disc is fitted near the southern axis of each 'Chakra Yantra' bearing the meridian line and 60 'ghatika' markings (equivalent to 24 hours). A pointer is fixed in the hole provided in the southern axis of the Chakra, which moves on the graduated metal disc at the time of observation.

The sun or a planet is observed through the brass tube whose both extreme ends touch and move on the graduated circle when a celestial object is seen through the tube, its position on the circle indicates its Declination, the position of the pointer on the southern disc would indicate the Meridian Pass Time in 'ghatika' unit of time (1 ghatika is equal to 24 minutes) As 60 'ghatikas' are equivalent to 360 degrees on the disc, the Meridian Pass Time can be easily converted into Hour Angles of the celestial object thus observed.

14 THE ALTITUDE/AZIMUTH INSTRUMENTS

KNOWN as the 'RAM YANTRAS', perhaps, after the name of Maharaja Ram Singh, these two cylindrical massive structures



Both the complimentary parts of the
Altitude/Azimuth Instrument

adorn the western fringe of the Jaipur Observatory. Built in masonary and stone, both the Ram Yantras look identical, though they are meant for observations at alternate time, as they are complimentary to each other.

Consisting of twelve vertical columns and an equal number of horizontal slabs, the Ram Yantras represent the celestial sphere in inverted form horizon on the top and zenith at the bottom of a centrally situated metal post. There are 360 vertical lines representing the azimuth circles and 90 horizontal lines or altitude circles. Each degree is sub-divided by ten for the decimal calculations of azimuth and altitude of celestial objects during day and night.

During day, the shadow of the central post falling on the vertical line indicates the azimuth which is counted from the southern-most point of the horizon. The same shadow falling on the horizontal line indicates the altitude of the sun in degrees from the eastern horizon in the forenoon and from the western horizon in the afternoon. These celestial positions can be directly read on the graduated portions of the instrument as each line is distinctly marked.

As there is no such shadow of the central post during night, the observer has to go inside the instrument,place his eye on the graduated portions of the stone slabs in such a way that he can

see the particular heavenly body under observation through the top of the central post. The position of the eye on the scale of vertical and horizontal lines would indicate the azimuth and altitude of the heavenly body thus observed. The idea for providing two complimentary instruments is to allow the observer to go inside the instrument to move about freely to observe and calculate the altitude and azimuth of any celestial sphere at any time of day or night.

15 THE AZIMUTH INSTRUMENT

KNOWN as 'DIGANSHA YANTRA', the Azimuth Instrument is situated north of both the Ram Yantras and west of the Kapali Yantra. It consists of three circular constructions, one inside the other, made in the plane of horizon. There is a massive round structure of about 1 meter height at the centre which is encircled by a circular wall of the same height and of about 5 meter diameter. The outermost masonary circle of about 2 meter height is made of 8 meter diameter. All the three masonary structures have marble tops precisely graduated in 360 degrees each as they represent the horizon circles. The degrees are further sub-divided in decimals.

A cross-section of metal wires holds a ring exactly over the central point of the innermost structure represented by a metal knob. All the four metal wires are fastened in all the four directions,

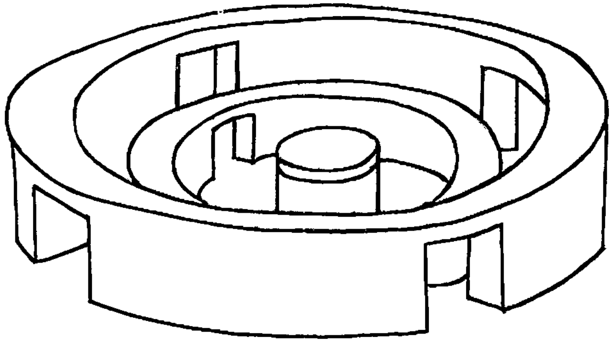
representing north-south and east-west. Four doors are also provided below these direction points to allow observers to enter the Yantra.

For determining the azimuth of the sun, the shadow of the ring falling on the floor is observed. A thread is tied to the knob at the centre and taken to the outermost wall passing through the shadow of the ring. The position of the thread thus stretched on the graduated circumference of the outermost wall would indicate the azimuth of the sun

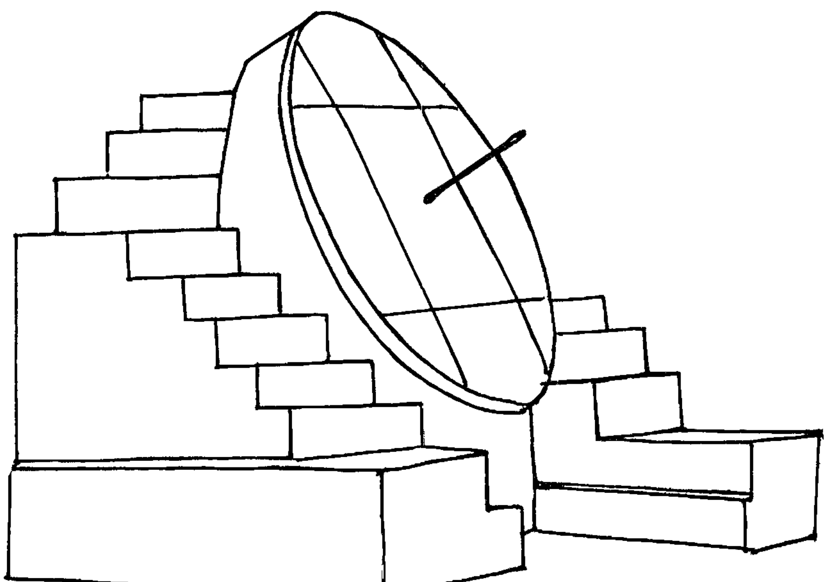
The sun's amplitude ('agra'), a kind of azimuth, at its rising and setting time can also be observed with the help of this Yantra in the same manner as explained above.

For observing the azimuth of heavenly bodies at night, the observer has to get inside the Yantra and lie down on its floor to look at the particular planet through the metal ring in such a way that the planet under observation, the hole of metal ring, and the eye of the observer fall in a straight line. The position of the eye is marked on the floor and a thread, tied to the central knob, is taken through it to the outermost circumference of the Yantra. Its reading would indicate the azimuth of that particular heavenly object thus observed.

It is a kind of a stable and massive Compass which indicates all the four directions exactly and also inclination of heavenly bodies from them.



The Azimuth Instrument



The abandoned Ecliptic Instrument

16. THE ABANDONED ECLIPTIC INSTRUMENT

ON entering the observatory, one comes across, towards right, a huge red sandstone round structure of about 3 meter diameter which is worthy of mention here.

As a matter of fact, the astronomer Maharaja built this structure inclined to the plane of equator ($23\frac{1}{2}$ degrees) to be the stable base of a big metal ecliptic device (as explained earlier for Ecliptic Instrument No.5). It has a thick metal rod at its centre around which the proposed metal device (Ecliptic Circle of $23\frac{1}{2}$ degrees) was to be attached and rotated for ecliptic measurements.

The circumference of this Equatorial base is graduated in 60 ghatikas and minutes and seconds of arc.

Later on the Maharaja and his team mates realised that it would be too big a metal device to make and it would be cumbersome and impractical to rotate it on this huge base. Thus, this impressive equatorial dial was abandoned and a smaller version of the Ecliptic Instrument (no.5) was made for actual observations of celestial longitudes and latitudes.

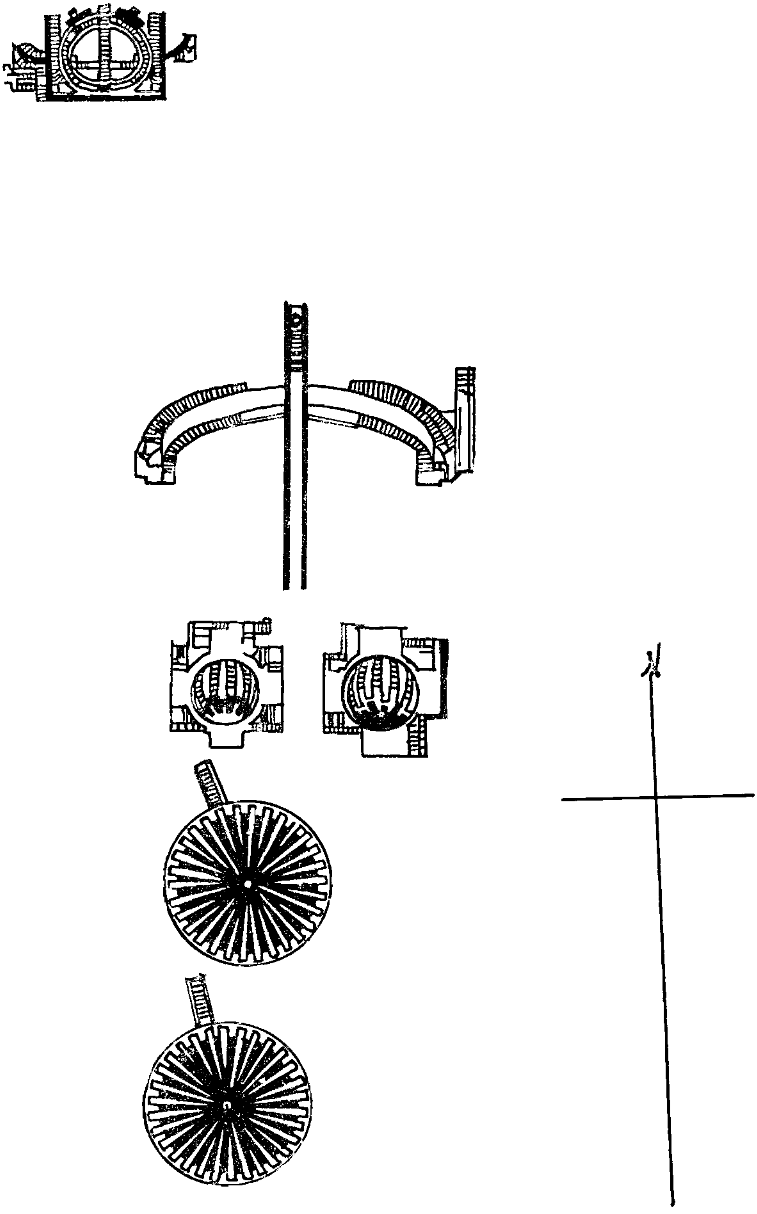
2. THE DELHI OBSERVATORY

Altitude	239 Metres (785 Ft.) above M.S.L.
Longitude	77° 13'5" East of Greenwich
Latitude	28° 39' North.

The association of the rulers of Amber (former capital of Jaipur) with the Moghul Emperors had been quite close since Raja Bhagwan Das of Amber of the 16th Century. Maharaja Sawai Jai Singh-II of Amber and Jaipur, maintained the same diplomacy and pledged his support to five Moghul Emperors who were his contemporaries, viz. Aurangzeb, Bahadur Shah, Jahandar' Shah, Farrukh Siyar and Mohammad Shah.

He, thus, frequented Delhi off and on for various diplomatic and military assignments. In the process, he left an everlasting imprint of his wisdom on the soil of Delhi by planting his first Astronomical Observatory there. Although built on an experimental basis, Delhi Observatory paved the way for four such other astronomical complexes which Maharaja Sawai Jai Singh constructed at Jaipur, Ujjain, Varanasi and Mathura during the first half of the eighteenth century.

This magnificent observatory, popularly known as the JANTAR-MANTAR, is located in the vicinity of Lok Sabha, the National Parliament. It forms a curious and picturesque view against the skyline of modern skyscrapers of New Delhi. The Delhi Observatory, termed as the "most surrealistic and logical landscape in stone," still remains a magnanimous monument of the ancient science of astronomy. Looked after by the Archaeology Department of Government of India, the 'Jantar-Mantar' is a National



The lay-out plan of the DELHI OBSERVATORY

Monument and boasts of being one of the most important and popular places of sight seeing in Delhi.

It seems that the construction of this Observatory was launched by the Maharaja in 1719 A.D., soon after the coronation of Mohammad Shah as Moghul Emperor of India and completed by 1724 A.D. The architects and astronomers of Maharaja Sawai Jai Singh's Court were associated with the construction of this 'Vedhashala'. Prominent among them were Pandit Vidyadhar, Pandit Jagannath Samrat and Pandit Kewal Ram Sharma. Assisted by Pandit Jagannath Samrat, Sawai Jai Singh spent about seven years in celestial observations here to prepare astronomical tables and star catalogue which came to be known as 'Jij-e-Mohammad Shahi' after the Moghul Emperor, Mohammad Shah (1719-48 A.D.).

Some European missionary astronomers and scholars also included this Observatory in their itinerary. French astronomer Père Boudier, accompanied by his assistant, visited Delhi Observatory on his way from Chandernagore to Jaipur in 1734 A.D. Another European scholar Tieffenthaler made three trips to Delhi to meet German astronomer Andre Strobel. They both carried out astronomical observations in this observatory in 1743 A.D., the year of astronomer Maharaja's death. Monsieur D' Anville also made astronomical calculations in this observatory in 1775 A.D.

Maharaja Sawai Madho Singh-II of Jaipur, the worthy descendant of the astronomer Maharaja, took keen interest in the

restoration of some of the weather-beaten instruments of this observatory and deputed his court astronomer Pandit Gokul Chand Bhavan who executed the job in 1910-12 A.D. Pandit Kedar Nath Sharma of Jaipur played an important role in the restoration of Composite Instrument (Mishra Yantra) in marble.

Then,this historic 'Jantar Mantar' remained neglected for several years until its stars changed favourably at the time of the Asian Games in 1982 A.D., when its Composite Instrument was chosen as the logo of Asiad '82. Most of its instruments were also restored in lime and plaster by the Central Archaeology Department. As a result, the observatory wears a better look now.

During the process of restoration, the lower portions of both the quadrants of the Samrat Yantra (the Supreme Instrument) were unfortunately flattened which has altered the original shape and function of the instrument. The water-logged around this Equatorial Sun Dial does not seem to find any outlet and thus, the dials (quadrants) remain inaccessible which is a pity for the authorities as well as visitors.

The authorities concerned could do a good job by restoring and graduating all the 'Yantras' in marble and sandstone on the lines of Jaipur Observatory to make it an everlasting and functional stone observatory of India. The quadrants of the Sun Dial, already tampered with, must be rectified and graduated. The water

should also be drained out of the base of this Yantra at any cost. Installation of a life-size statue of Maharaja Sawai Jai Singh in the observatory premises would be a befitting tribute to the memory of the founder of Delhi Jantar Mantar.

ASTRONOMICAL INSTRUMENTS AT DELHI

1 THE COMPOSITE (MIXED) INSTRUMENT (MISHRA YANTRA)

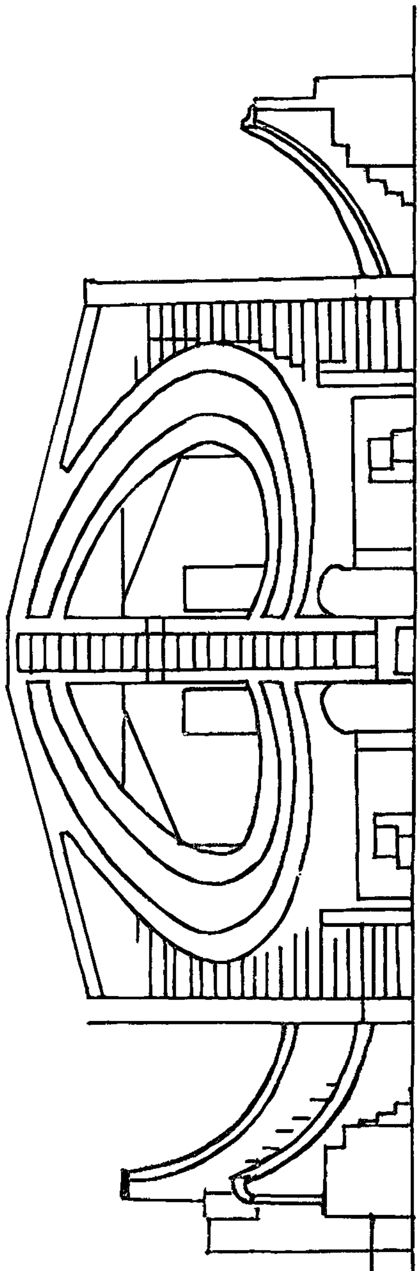
ANCIENT Hindu astronomers knew well to draw Meridian circles but Maharaja Sawai Jai Singh excelled them by constructing this Mixed Instrument comprising of various meridian circles in such a way that the inclination of their vertical points from the zenith became equivalent to the latitude of their respective places.

This curious looking astronomical structure comprising five different instruments has a significant place in observational astronomy, which is a unique feature of 'Jantar-Mantar' at Delhi.

The visitor comes across this heart-shaped yantra on entering the observatory premises. It consists of five various astronomical devices as following :

I. THE MERIDINAL WALL INSTRUMENT (DAKSHINOVRITTI BHITTI YANTRA)

THE small Meridinal Wall Instrument is



The Composite Instrument

made on the eastern wall of the Composite Instrument. This happens to be the smallest instrument of its kind available in Sawai Jai Singh's observatories.

It is a small semi-circle studded on the wall which accurately lies in the plane of meridian of Delhi. The semi-circle is graduated in 180 degrees which are further sub-divided into minutes. Then there is a hole provided at the centre of this semi-circle where a peg is fixed to tie a thread for the purpose of observation. For celestial observations, a thread is tied to the peg fixed at the bottom and then the thread is stretched to the graduated arc to align it with the sun exactly at its (sun's) Meridian Pass Time (12 O'clock local time). The observer has to lie down and look at the sun with the medium of the peg and thread. The same process is adopted for the observation of heavenly bodies at night when they cross the Local Meridian.

Obviously, two persons are required for such observations as one has to hold and align the thread with the celestial bodies while the other to observe the same lying down below. The position of the thread on the graduated arc indicates the altitude of heavenly bodies at their Meridian Pass Time. The graduations on this 'Bhitti Yantra' are done in lime and plaster which can hardly be read now.

For detailed description of its purpose and function, the Meridinal Wall Instrument of Jaipur Observatory (No.8) may be

referred to.

II. THE SMALL EQUATORIAL SUN-DIAL (LAGHU SAMRAT YANTRA)

THE Small Equatorial Sun Dial forms the eastern and western parts of the Mixed Instrument. A triangular wall placed in the plane of meridian of Delhi, is the Sun-Dial's gnomon which is separated by the Central (Niyat Chakra) Instrument, thus, providing two masonary triangles whose shadow is observed on the graduated dials.

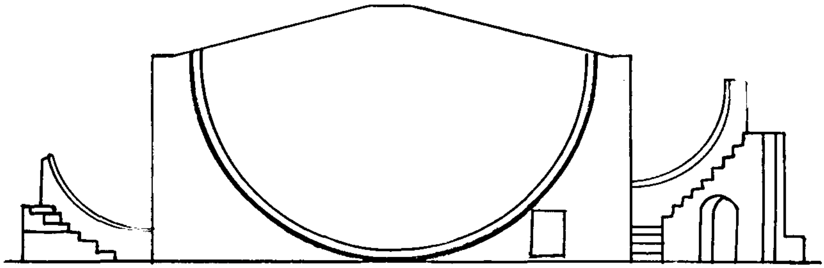
Both masonary triangles make an angle of 28 degrees 39 minutes (equivalent to the latitude of Delhi) with the horizontal plane and are flanked by two quadrants on both sides, which are placed in the plane of celestial equator(inclined by 23°27'). The western quadrant is meant for observations before mid-day and the eastern dial for afternoon. The quadrants are graduated in ghatikas' where one ghatika' is equivalent to 24 minutes. Each 'ghatika' is sub-divided into 6 parts, each equivalent to 4 minutes. Again 4 minutes are divided into 10 parts, each equal to 24 seconds and further sub-divisions indicate the minimum measurement upto 12 seconds for determining Time correct to 12 seconds. The hypotenuse of the triangles (gnomons) are also graduated in the scale of tangent for the calculation of declination of celestial objects.

The graduations on its quadrants and gnomons were originally done in lime and plaster which are not clearly visible any more as they have been rubbed off by time and weather.

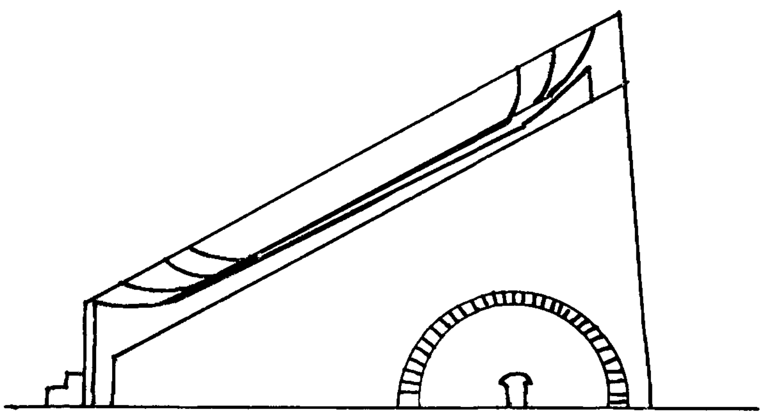
In purpose and function, the Laghu Samrat Yantra is identical to its counterpart at Jaipur observatory (No.1) which may be referred to for detailed descriptions. However, the following Table of Time Difference can be used by the observers to find out the Indian Standard Time on the basis of the Local Delhi Time determined on the Equatorial Sun Dial.

	5th Mi.Se.	10th Mi.Se.	15th Mi.Se.	20th Mi.Se.	25th Mi.Se.	30th Mi.Se.
JANUARY	26.30	28.30	30.33	32.10	33.39	34.28
FEBRUARY	35.12	35.26	35.21	37.58	34.18	33.48
MARCH	23.46	31.35	30.12	28.35	27.15	25.26
APRIL	32.57	22.34	21.16	20.8	19.8	18.22
MAY	17.48	18.4	17.25	17.35	17.57	18.41
JUNE	19.28	19.20	21.8	22.32	23.36	24.38
JULY	25.35	26.25	26.59	27.23	27.34	27.28
AUGUST	27.6	26.28	25.37	24.32	23.15	21.30
SEPTEMBER	19.54	18.12	16.25	14.38	12.54	11.8
OCTOBER	9.38	8.14	6.59	5.58	5.16	4.38
NOVEMBER	4.45	5.3	5.42	6.44	8.4	9.44
DECEMBER	11.40	13.38	16.8	18.38	21.8	24.4

The mean difference of the Time of Delhi is 21 minutes 8 seconds.



The Cancer Zodiac Instrument



The Meridinal Wall Instrument

III. THE CANCER ZODIAC INSTRUMENT (KARK RASHIVALAYA)

THE Cancer Instrument is in the form of a semi-circle which is based on the wall of Mixed Instrument facing north. The semi-circle is graduated in 180 degrees which are further sub-divided into minutes. The surface on which this Yantra is engraved in lime and plaster, is inclined to the vertical plane of Delhi by (28°39'-23°27½) 5°.12' which is the Zenith Distance of Cancer. This inclination makes this wall the Cancer Zodiac Instrument.

When the sign of Cancer culminates on the Local Meridian at a particular time, this instrument is used to find out the longitudes of planets. When Cancer passes the Local Meridian at a certain time during day (that happens for six months in a year), longitude of the sun can be determined by observing the shadow of the peg (provided upward on the wall) as it falls on the big arc graduated in degrees and minutes below. By dividing the longitude of the sun by 30, one can also know in which Zodiac sign the sun is passing at the time of observation. During night, the longitudes of planets can be found out when Cancer culminates on the Local Meridian which happens for other six months of the year.

The Cancer Instrument was the fore-runner of the twelve Zodiac Instruments built at the Jaipur observatory for determining the longitudes and latitudes of

planets all the twenty four hours, which may be referred to for full details. (No.10)

IV. THE AMPLITUDE INSTRUMENT (AGRA YANTRA)

NORTH of the western quadrant of small Equatorial Sun Dial, there is one more quadrant lying in the horizontal plane which is attached to the triangular gnomon of the Sun Dial. Known as the Amplitude Instrument, it is graduated in degrees and minutes.

This attachment is used to determine the difference of Sun-Rise Time from 6 O' clock. The Yantra indicates the accurate time of sun-rise every morning and, therefore, it can be used only at the time of sun-rise for a minute or two.

The shadow of the triangular structure (gnomon) falls on this western quadrant immediately at the time of sunrise showing the difference from 6 O'clock,which is the exact west point on this dial. Obviously, on two equinoctial days,i.e., 21st March and 23rd September, the shadow falls on the exact west point of the quadrant where 6 O'clock is marked, showing no amplitude as the days and nights are of equal duration on these two days every year.

V. THE STABLE (FIXED) INSTRUMENT (NIYAT CHAKRA YANTRA)

THIS heart-shaped instrument forms the central parts of the COMPOSITE Instrument. This is a unique

astronomical device in the world.

At the very centre of this Yantra, there is a triangular gnomon making an angle of 28 degrees 39 minutes equivalent to the latitude of Delhi. This gnomon points towards the celestial North Pole. There are four semi-circles, two on each side of the triangular structure, with their centres falling on the eastern and western edges of the gnomon where two holes are provided for fixing a rod or a stick used as a pointer for the observation of its shadow when it falls on the graduated semi-circles. These four semi-circles are made inclined to the plane of Delhi Meridian by four different angles i.e. 77°16'W, 68°34'W, 68°1' and 75°54'E corresponding to the meridians of four international places whose longitudes are different from Delhi's by the angles mentioned above. These respective places are Greenwich (England), Zurich (Switzerland) towards west and Notkey (Japan) and Seritchew (Pic Island in the Pacific, east of Russia) in the east. Incidentally, all these places had astronomical observatories:

Greenwich	Lat. 51°29' N.	Long 0°00'
Zurich	Lat. 47°26' N.	Long 8°22' E.
Notkey	Lat.43°33' N.	Long 145°17' E.
Seritchew	Lat.48°6' N.	Long 153°12' E.
Delhi	Lat.28°39' N.	Long 77°13' E.

The purpose of this Yantra is to observe mid-day (Noon) at the above mentioned four observatories and to determine the declination of the sun at 6.52 A.M.,

7.24 A.M , 5.8 P.M. and 4.36 P.M.(Delhi Mean Time). When the pointer is held in the hole on The Western edge of the gnomon at 6.52 A.M. and 7.24 A.M.(Delhi Meantime), its shadow will invariably fall on the outer and inner semi-circles towards the west indicating mid-day at Notkey and Seritchew respectively. Similarly, the pointer held on the eastern edge of the gnomon at 5.8 P.M. and 4.36 P.M. (Delhi Mean Time), will have its shadow on the outer and inner semi-circles towards the east, indicating the mid-day at Greenwich and Zurich respectively. This way, the mid-day at the above mentioned four international cities can be determined with the help of this magnificent instrument. Accordingly, the Local Time, Meridian Pass Time and Declination of the Sun at Noon at these international places can be calculated at Delhi itself.

It may be noted that the shadow of the pointer on different semi-circles can be observed only at the above mentioned specific timings as the mid-day at these four foreign places corresponds exactly to the Delhi Time given above. This is the only Yantra at Delhi which is restored in white marble and neatly graduated and which is in serviceable condition.

A. MISCELLANEOUS DEVICES

SOUTH of the Composite Instrument mentioned above, is a platform measuring 47 feet by 43 feet which had a quadrant

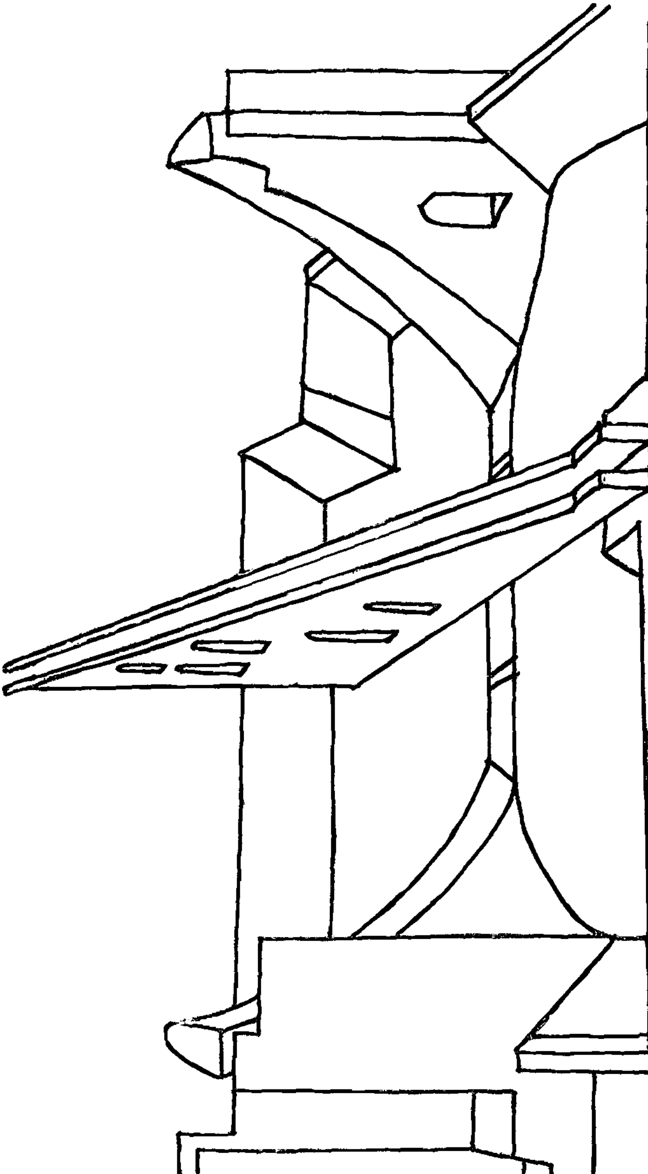
of 20 feet radius on it. It seems that it was used for making the experimental graduations before making the final scale markings on the quadrants and gnomons of the above described Misra Yantra. This could have also been used to make the plan and scale markings of the Big Equatorial Sun Dial.

There is, however, no trace of the experimental scale markings any more although the platform still exists.

South west of the Misra Yantra, one comes across two pillars which were used to hang an Astrolabe in olden days. It is believed that the same life-size metal Astrolabe was taken to Jaipur Observatory where it can still be seen.

Another significant feature of these masonary pillars is that on 22nd December, which happens to be the shortest day of the year and which marks the beginning of Winter Solistice, the shadow of the round pillar covers the rectangular pillar at mid-day. On the contrary, there is no shadow of the rectangular pillar at mid-day on 20th June, the longest day of the year which marks the beginning of Summer Solistice.

This happens due to the 5.12 degree inclination of the rectangular pillar as the sun is inclined 23°27' north from the celestial equator on the 20th June and the latitude of Delhi is 28°39'. Hence the pillar is inclined by (29°39' - 23°27' =) 5.12 degrees which is the zenith distance of the Sun on the 20th June every year.



The Big Equatorial Sun-Dial

2. THE BIG EQUATORIAL SUN-DIAL (BRIHAT SAMRAT YANTRA)

THIS is the loftiest instrument of Delhi Observatory and the second biggest Samrat Yantra built by Sawai Jai Singh in his five observatories. It is about 70 feet high, 126 feet from East to West and 115 feet from North to South. It is constructed in a quadrangular excavation and steps are provided to approach the dials.

Like its counterpart at Jaipur Observatory, this Yantra also consists of a triangular wall situated in the plane of meridian of Delhi. Its hypotenuse, which serves as a gncmon, makes with its base an angle of 28 degrees 39 minutes, equivalent to latitude of Delhi. Thus, the gnomon of the instrument points towards the celestial North Pole.

The triangular structure is flanked by two quadrants, each of 50 feet radius and are made parallel to the celestial equator and are inclined by 23 degrees 27 minutes. Thus, the quadrants lie in the plane of the celestial equator. The edges of both sides of the gnomon are graduated with the scales of tangent and the quadrants are graduated in hours, minutes and seconds.

The purpose of the Samrat Yantra is to determine Local Time, Indian Standard Time, Zenith Distance, Meridian Pass Time, Altitude of Sun at noon and Declination of Sun, stars and planets during day and night.

This instrument is identical to its counterpart at Jaipur observatory (No.9) which may be referred to know details about the method of observations and calculations of the above mentioned phenomena.

The quadrangular excavation in which this giant instrument is constructed, is filled with water, making the lower portions of the dials inaccessible for observations and calculations. The lower portions of the quadrants joining the triangular gnomon have also been tampered with and the curves wrongly flattened in the name of restoration.

3. THE HORIZONTAL SUN-DIAL (DHOOP-GHARI)

65 steps take one on the top of the gnomon of Samrat Yantra where a round and thick pillar is erected. A Horizontal Sun Dial is made on the top of this round structure. A triangular metal gnomon of 28 degrees (North-South) is provided at the centre of this Horizontal Sun-Dial which is meant for the observation of Local Time of Delhi during day and night.

During day, the shadow of the triangular gnomon falling on the graduated Dial indicates the Time whereas at night, the Time is determined by observing the Meridian Pass Time of certain prominent stars. The particular star is looked by keeping the eye on the graduated edge of the pillar in such a way that the star under observation, seems touching

the gnomon of the Horizontal Dial. With the help of the Meridian Pass Time of this star, the Time can be known by calculation. The Horizontal Sun Dial is placed on a raised pillar to facilitate such observations.

It is a pity that visitors and observers have no access to this Yantra which also provides a spectacular view of New-Delhi's skyline and a bird's eye view of the observatory complex.

THE SEXTANT INSTRUMENT (SHASHTHANSHA YANTRA)

THE eastern quadrant of the Big Equatorial Dial (Samrat Yantra) is supported by a chamber which contains another instrument, the Sextant Instrument, consisting of a graduated arc of 60 degrees for the observation of Meridian Altitude and Declination of the sun at noon which shines through the tiny orifices provided in the roof above the arc, as and when it (sun) crosses the local Meridian exactly at mid-day. The chamber containing this instrument is closed now and the Sextant is inacessible.

Unlike two Sextants built on both sides of the Samrat Yantra at Jaipur, only one Sextant was made at Delhi.

The further details of the Sextant Instrument are given in the description of the same device at Jaipur (No.9B).

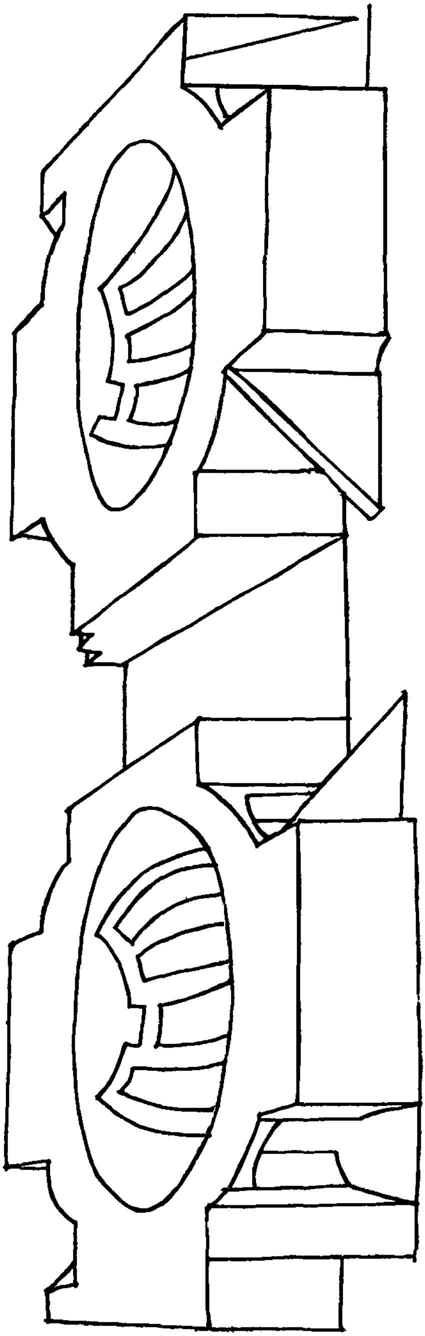
4. THE ARMILLARY SPHERE INSTRUMENT (JAI PRAKASH YANTRA)

THIS Hemispherical Instrument is situated south of the Big Equatorial Sun Dial. It consists of two hemispheres, each of 27 feet 6 inches diameter, which are concave in shape and sunk into the raised platforms. The bowl shaped instruments represent the interior sphere of the visible heavens. The celestial sphere is turned upside down as the rim of the instrument represents the horizon divided into 360 degrees and its bottom, the zenith. Both the instruments are complimentary to each other as the sectors in one correspond to the space in the other which is done to make every part of the instrument accessible for observations an calculations during day as well as night.

There are six sectors in each instrument which had the circles of Altitude, Azimut Declination, Meridian, Equator, Tropics and Zodiacs engraved on them in lime and plaster which have now completely disappeared. Hence no calculations can be made on this instrument even though its entire concave surface was restored at the time of the Asiad '82.

The purpose of this yantra is to observe and calculate Local Time, Azimuth, Meridian Pass Time, Zenith Distance, Declination of the Sun and planets and the starting time of 10th House of the Zodiac Signs etc., round the clock.

Originally, a metal post of the height parallel to the upper rim, was fixed at



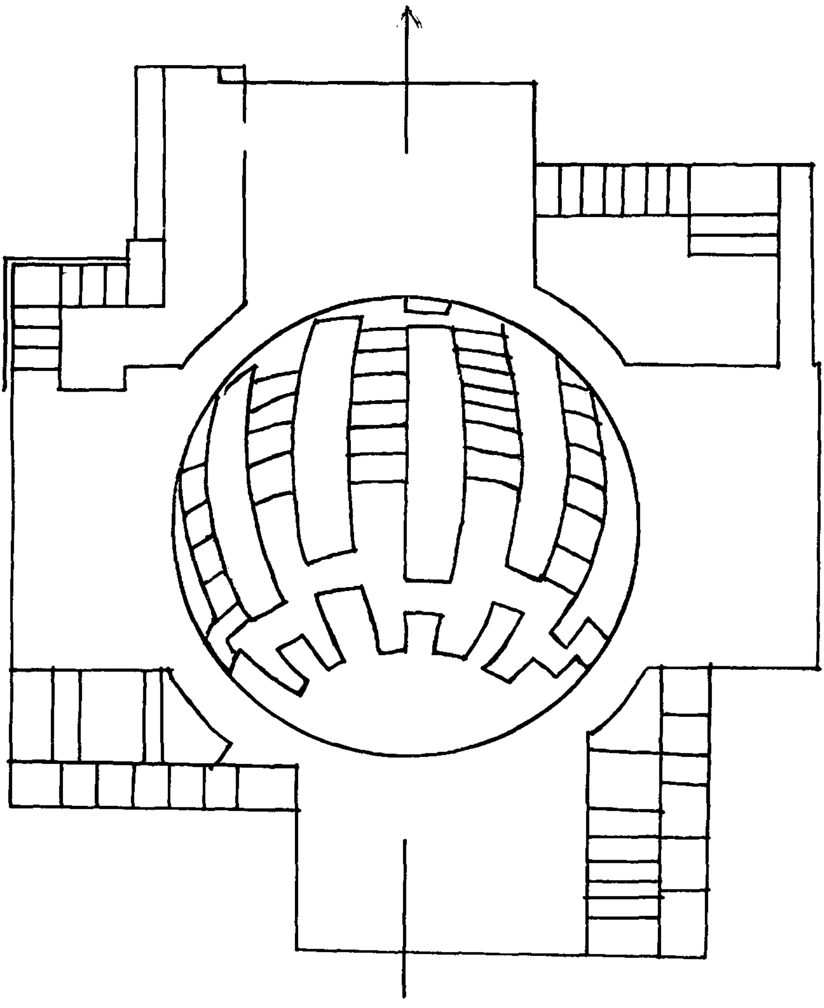
The Armillary Sphere Instrument

the centre of the instrument where a big hole provided for this purpose can still be seen although the metal post has disappeared since.

The shadow of the tip of this central post (Pointer) was observed while falling on the graduated surface of this instrument to determine different positions of the Sun in the sky. At night, the observer has to go down, keep his eye somewhere on the graduated sectors and observe a star or a planet through the tip of the metal post in such a way that the heavenly body and the tip of the metal post fall in a straight line with the eye of the observer kept on the graduated scale. The position of the eye on the scale would indicate different placements of this celestial object in the sky.

For the method of observations and calculations, it is almost identical to its counterpart at Jaipur Observatory (No.11) which may be referred to for further details.

Its counterpart at Jaipur is smaller in size but the entire instrument is in white marble which bears the complete scale marking of the heavenly sphere. Instead of a metal post fixed at the centre, as at Delhi, the Jaipur Instrument has a cross-section of wires stretched east-west and north-south. This cross section of wires holds a metal ring at the centre parallel to



One of the two complementary parts
of the Armillary Sphere Instrument

the horizontal rim of the instrument. Its shadow falls on the graduated concave surface of the instrument and this directly indicates various positions of the sun in the sky. At night, the heavenly bodies are observed through the hole of the ring from down below and thus, the position of the eye on the graduated slabs indicates the placements of celestial objects at night.

THE EQUINOCTIAL OBSERVATION

THE Jai Prakash Yantra at Delhi has a unique feature. There is a hole provided in its southern wall for the purpose of observation of Sun's equinoctial position. The wall's surface having this hole is made inclined by 28 degrees 39 minutes equivalent to the latitude of Delhi, so that the rays of the Sun enter into the small chamber below as soon as the sun touches the equinoctial points. This happens only twice a year, viz., the 21st March and 23rd September when the Sun comes on the equator resulting into equal duration of day and night.

5. THE ALTITUDE/AZIMUTH INSTRUMENT (RAM YANTRA)

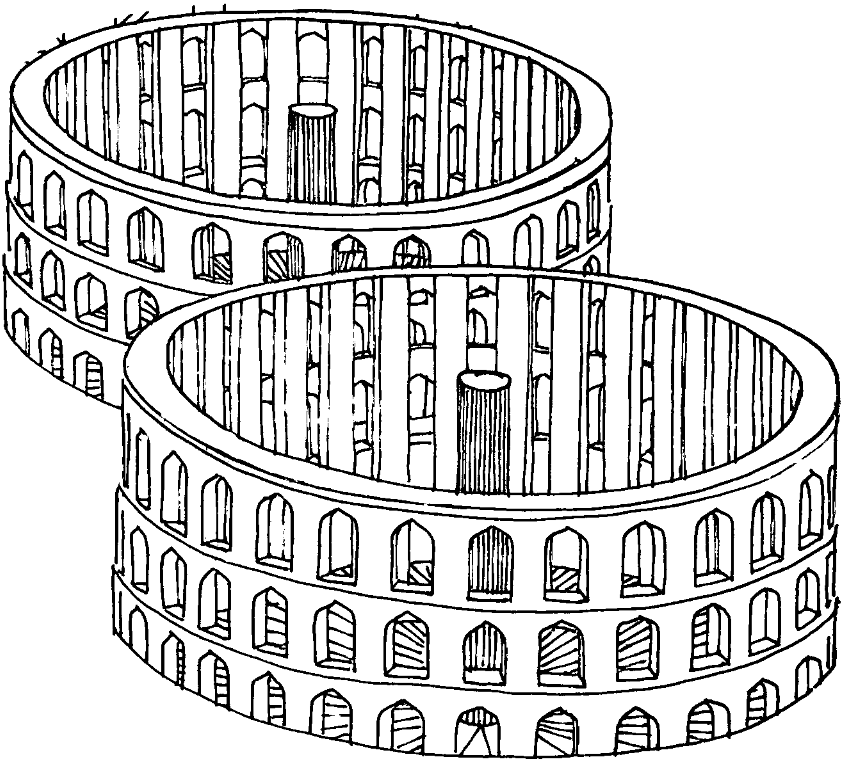
THE Ram Yantra is situated in the southern part of the observatory. It is in the form of two circular structures each of 24 feet 6 inches diameter. Each instrument is divided

into 30 sectors and 6 degrees each in such a way that the space in one, corresponds with the sectors in the other, thus, making them complimentary to each other. The inner sectors are raised 3 feet above the ground in order to make any part of the instrument accessible for the purpose of observations at any time during day or night.

The upper rim of the yantra represents the horizon and parallel to it, 90 Altitude circles of one degree each are drawn upto the centre of the instrument, which represents the zenith. 360 vertical lines are also graduated which intersect the altitude circles and are known as Azimuth circles. There is a thick pillar of 5 feet 4 inches radius raised at the centre of both these complimentary instruments. The pillar is divided into 60 parts by 30 stripes.

The shadow of this thick pillar is observed while falling on the graduated vertical and horizontal sectors to determine the altitude and azimuth of the Sun. For accurate reading, its only the central point of the shadow of the pillar, which is taken into account.

At night, the observer can enter inside the instrument to place his eye on any part of the graduated sectors in such a way that he can see a planet/star through the top edge of the pillar The position of the eye on the graduated scale would indicate the altitude and



Both the complementary parts of the
Altitude/Azimuth Instrument

azimuth of the heavenly bodies at night The notches are also provided in betwee the graduated vertical sectors of the instrument so that the observer may climb higher to align the heavenly objects at lower altitude with his eye and top of the pillar. Maharaja Sawai Jai Singh constructed a Smaller Ram Yantra at Jaipur which has a thin metal post instead of a thick masonary pillar at the centre. Obviously, the sharper shadow of the thin metal pole in Jaipur's Ram Yantra indicates more accurate readings comparatively.

The purpose of the Ram Yantra is to determine the Celestial Altitude and Azimuth of Sun, stars and planets during day and night. Its almost identical to its counterpart at the Jaipur Observatory (No. 14).

The graduations which were originally done in lime and plaster on the inner surface of these instruments, have now disappeared and therefore, no observations and calculations are possible now. The Yantra needs facelift urgently.

3. UJJAIN OBSERVATORY

Altitude 492 Meters (1500 Feet) above M.S.L.

Longitude 75°45' East of Greenwich

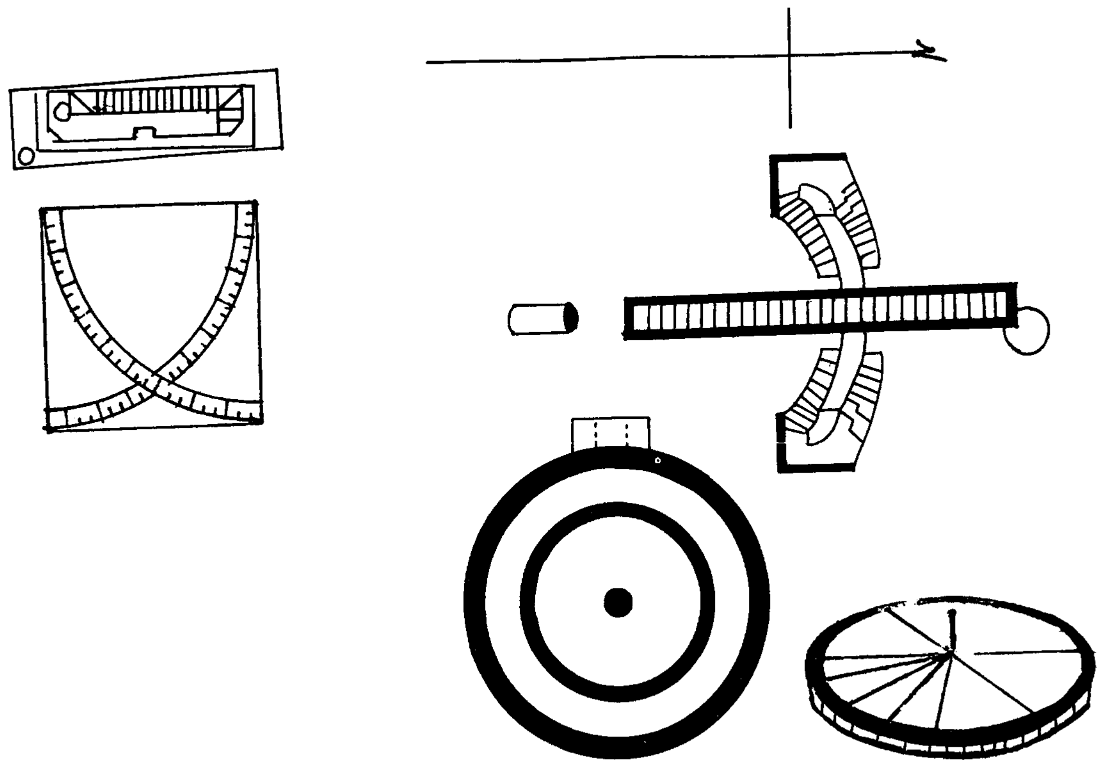
Latitude 23°10' North

Ujjain was to ancient India what Greenwich is now to the world. The

ancient Hindu astronomers regarded Ujjain as situated on the Prime Meridian (Zero Longitude) and astral calculations were done with reference to the Meridian of this ancient seat of astronomy. A number of astronomical references are cited in ancient Hindu treatises on astronomy including "Surya Siddhanta" (Circa 3rd century) and "Panch Siddhantika" of Varahamihira of 6th century A.D.

Ujjain was considered as the place of zero longitude and its latitude was calculated as "one sixteenth of the whole circumference north of the equator" which is equivalent to 22°30'. It was also believed in ancient times that sun changed its course towards South after completing its farthest North journey near the Zenith point of Ujjain. It was the same point where the Meridian Line of ancient Lanka crossed the Tropic of Cancer and therefore, the Meridian Line of Ujjain became the Prime Meridian (longitude zero) of ancient India.

The significance of Ujjain, as an ancient seat of learning, is very well reflected by the fact that Lord Krishna came here in his childhood to pursue studies at the 'Ashram' of legendary Guru Sandipani during the Mahabharata period. Euridite scholars of astronomy and mathematics, viz; Varahamihira (6th century), Brahmagup (7th century) and Bhaskaracharya II



The site plan of the UJJAIN OBSERVATORY

(12th century) practised and taught astronomy here. Observational astronomy reigned supreme then as they had invented several astronomical devices for the actual observation of celestial phenomena. A detailed description of such astronomical instruments is given in the author's earlier book entitled "STONE OBSERVATORIES IN INDIA".

Referred as Avanti or Ujjayani in ancient scriptures, Ujjain was a well established centre of astronomical studies and celestial observations during the antiquity. Ujjain reached its zenith during the golden reign of king Vikramaditya II of Gupta dynasty who went all out to patronise all spheres of learning including astronomy and mathematics.

Another significant feature of ancient Ujjain is that the two important Hindu Eras viz; the 'Vikram Samvat' prevalent North of the Narmada and the 'Shaka Samvat' of the South originated here. The Vikram Samvat era was introduced by king Vikramaditya I in 57 B.C. and the Shaka Samvat era heralded here in 78 A.D. Both the eras of Hindu Calendar are followed all over the country even today. This quiet town, located in Central India (Madhya Pradesh), still bears some of the ancient relics. It is one of the supreme seats of Lord Shiva, the Mahakala or the Mahakaleshwara - in the country.

Himself an ardent follower of Hindu traditions and ethics, Maharaja Sawai Jai

Singh II of Jaipur truly realised the importance of Ujjain's location in close proximity of Tropic of Cancer and decided to construct the third of his five astronomical observatories here when he was appointed Governor of Malwa by Moghul Emperor Mohammad Shah in late twenties of the 18th century. The construction of Ujjain Jantar-Mantar was completed by 1734 A.D. The observatory is ideally situated on the southern bank of the holy Kshipra river at the outskirts of Ujjain. Some foreign missionaries and scholars have also praised this astronomical monument in their travelogues and memoirs. They include Father Tieffenthaler (1743 A.D.) and Dr. William Hunter (1792 A.D.) among several others.

Maharaja Sawai Madho Singh II of Jaipur took keen interest in the preservation of his glorious ancestor's scientific creation and sent learned Pandit Gokul Chand Bhavan to restore this observatory in 1922 A.D.

It is ironical that the Ujjain Observatory which was built by Maharaja Sawai Jai Singh of Jaipur and even restored by his descendants has been named as 'Jiwajee Rao Vedhashala' after the name of the ruler of Scindia House of Gwalior and thus, the name of its builder is unfortunately wiped out. Not only the name of this 'Jantar-Mahal' should be changed to 'Sawai Jai Singh Observatory' but a statue of the Royal-Astronomer

of Jaipur be installed to pay true homage to the memory of the builder of magnificent Jantar Mantars in India.

INSTRUMENTS OF UJJAIN OBSERVATORY

(1) EQUATORIAL SUN DIAL (Samrat Yantra)

THIS triangular gnomon makes an angle equivalent to the latitude of Ujjain and lies in the plane of local meridian (North-South). Its flanked by two quadrants (East-West) which are inclined to the plane of celestial equator. This Yantra indicates the Local (Solar) Time of Ujjain which can be converted to the Indian Standard Time by utilising the following Table of Difference of Time.

The Table of Difference of the Time of Ujjain and the Indian Standard Time:

	5th Mi.Se.	10th Mi.Se.	15th Mi.Se.	20th Mi.Se.	25th Mi.Se.	30th Mi.Se.
JANUARY	32.18	34.26	36.21	37.58	39.17	40.16
FEBRUARY	41.00	41.14	41.9	40.46	40.6	39.36
MARCH	38.34	37.23	37.00	34.23	33.3	31.14
APRIL	29.45	28.22	27.2	25.56	24.56	24.10
MAY	23.36	23.52	23.13	23.23	23.45	24.29
JUNE	25.16	25.8	26.56	23 20	29.24	30.26
JULY	31.23	32.13	32.47	33.11	33.22	33.18
AUGUST	32.54	32.16	31.25	30.20	29.3	27.18
SEPTEMBER	25.42	24.00	22.13	20.26	18.42	16.56
OCTOBER	15.26	14.2	12.47	11.46	11.2	10.36
NOVEMBER	10.33	10.51	11.30	12.32	13.52	15.32
DECEMBER	17.28	19.26	21.56	24.26	26.55	29.52

(2) **HEMISPHERICAL SUN-DIAL (Narivalaya Yantra)**

This mini Sun-Dial is inclined to the plane of equator and has a metal gnomon at its centre.

(3) **AZIMUTH INSTRUMENT (Digansha Yantra)**

This circular structure is made in the horizontal plane of Ujjain and has a gnomon at its centre.

(4) **MERIDINAL WALL (TRANSIT) INSTRUMENT (Dakshinovritti Bhitti Yantra)**

This vertical wall lies accurately in the plane of local meridian.(North-South) and has two 60 degree sextant arcs inlaid on its eastern face. There are two metal gnomons fixed on top of both the arcs.

(5) **HORIZONTAL SUN-DIAL (Dhoop Ghari)**

Its situated on top of the Meridinal Wall Instrument and lies in the horizontal plane. It has a metal gnomon at its centre.

The above mentioned five astronomical instruments are identical to their counterparts at the Jaipur Observatory which may be referred to for the details of the principle of their constructions and functions.

(6) HORIZONTAL PLANE LEVELLER (Dharatal Yantra)

It is located between the Equatorial Sun Dial and the Hemispherical Sun Dial and was meant to verify the perfect horizontal plane for the construction of astronomical instruments.

(7) GNOMON INSTRUMENT (Shanku Yantra)

The Shanku Yantra is a unique feature of Ujjain Observatory. It consists of a circular platform of 22 feet 8 inches diameter in the horizontal plane of Ujjain and a 4 feet high "Shanku" (gnomon) is vertically placed at its centre. The platform is graduated in 360 degrees, each of 6 sub-divisions.

Seven red sandstone stripes paved from the centre of this circular structure indicate the West and North directions. They represent different tropical signs and the shadow of the gnomon travels along with them on particular days of the year. On the equinoctial days (21st March and 23rd September) when the days and nights are of equal duration, the shadow of the gnomon coincides with the straight red line representing the Celestial Equator (Tropical Libra and Aries) as marked on the platform. The latitude of the place can also be calculated with the help of the shadow of the gnomon at noon on either of these equinoctial days when the shadow travels on the equinoctial line only.

Two red stripes towards the extreme North and the extreme South represent the Tropical Capricorn (Sayana-Makara) and the Tropical Cancer (Sayana-Karka) respectively and consequently, the shadow of the gnomon travels on these lines on 22nd June and 22nd December respectively. One of the two lines drawn from the Tropical Capricorn towards the Celestial Equator represents the Tropical Aquarius and Sagittarius. It attracts the shadow of the gnomon on the 20th January and 22nd November. The other line adjoining to it represents the Tropical Pisces and Scorpio which gets the shadow of the gnomon on the 18th February and 23rd October. Similarly, the first line South of the Equator stands for the Tropical Taurus and Virgo where the shadow of the gnomon falls on the 21st April and 23rd August respectively. The second line South of the Equator is meant to capture the shadow of the gnomon on the 21st May and 23rd July as this line stands for the Tropical Gemini and Leo.

Thus, the Shanku Yantra is used to know the path of the Sun and the relative position of the observer on the earth. The apparent local time can be determined by calculating the zenith distance of the Sun with the help of the shadow. The altitude and azimuth of the Sun can also be found out with the shadow as the basis. In case of other celestial bodies too, their altitude and azimuth can be determined by necessary observations and calculations.

The elliptical red lines on the platform indicate the length of day as well as the position of the shadow on the dates mentioned above. The shape of these lines proves that the orbit of the earth around the Sun is elliptical.

4 VARANASI OBSERVATORY

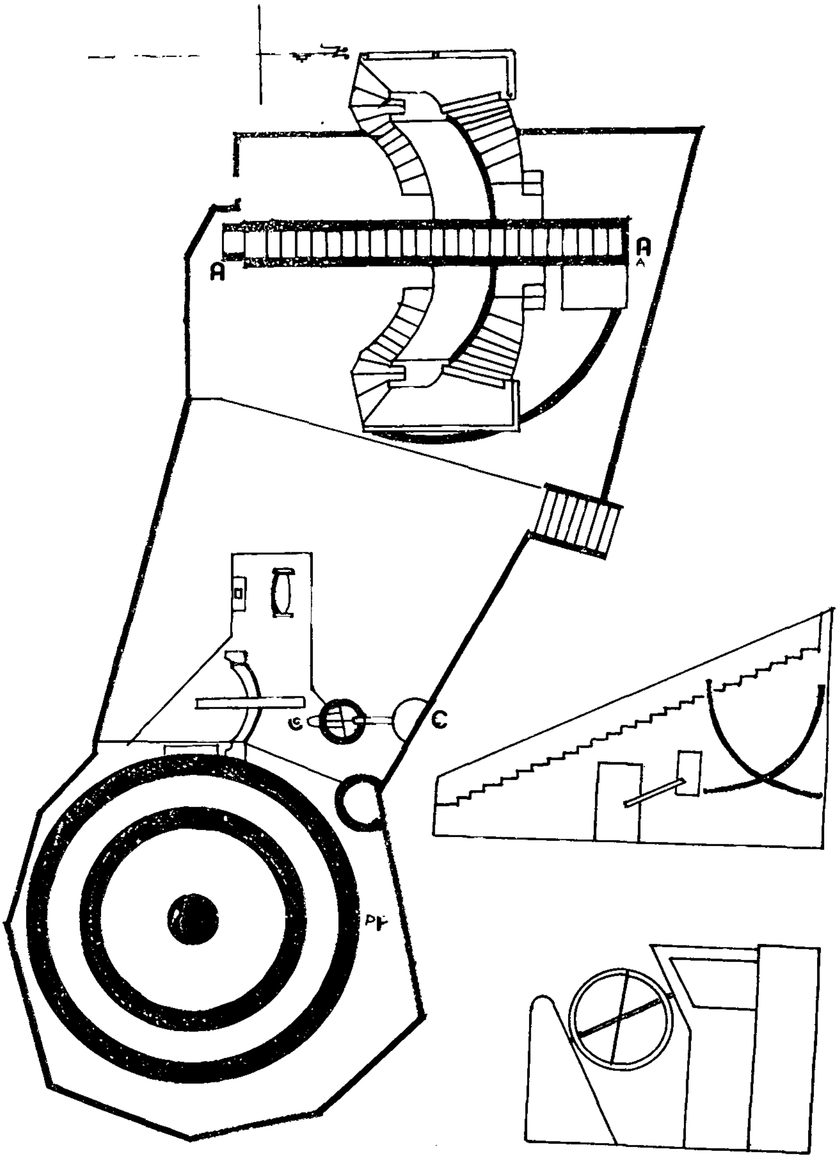
Altitude	80 Meters (350 feet) above M.S.L.
Longitude	83°2' East of Greenwich
Latitude	25°20' North

Varanasi, the very name sprouts some religious fervour. It is a great traditional centre of art, culture and learning. It is another famous seat of Lord Shiva, known as "Vishwanatha". This ancient place has the holiest helo around its every aspect. For Hindus, it is a place where a dip in the holy Ganges washes away all sins and purifies the spirit. The Ganges, to which "so many generations of men have looked for inspiration, at whose shrines they have quickened their faith" to quote late Sir Maurice Gwyer. It also bears a strong Buddhist cult for Lord Buddha gave his first sermon at Sarnath near here. Known also as Kashi and Banaras, Varanasi by all means, has been the epi - centre of all learning. Studies of Vedanta, Sanskrit Classics and Ethics were carried out here. Scholar Pandits and Brahmins trekked from all over the country especially to undergo the classics taught only here in the ancient times. The study of astronomy

and astrology was another attraction for them.

Maharaja Sawai Jai Singh II of Jaipur who had dubbed himself into the classics, did not leave Varanasi out of his astronomical peripheri. He left his lasting foot-prints by raising an observatory here on the bank of the Ganges to add a scientific dimension to this important seat of learning. He gave to the theory makers the practical, the authentic and the rational by this scientific creation. As a matter of fact, the observatories at Ujjain and Varanasi have stood as places of utmost benefit to the scholars as both these places were associated the most with astronomy and astrology.

Sawai Jai Singh selected the terrace of Man Mandir, a palatial edifice built by his glorious ancestor, Raja Man Singh of Amber, during the sixteenth century, as the site for the construction of his fourth Jantar Mantar. The Man Mandir Observatory is ideally situated on the Manikarnika Ghat, only a few hundred yards away from the famous Dasashvamedha Ghat; which can be approached from the river side or the market side through a meandering narrow by lane. The lofty site provides a panoramic view of the sacred Ganga curving its flow into the ancient city and going further away. Besides, it provides the unobstructed view of the skies and the horizon above the distant eastern bank of the Ganga which was very much thought of by its founder builder and his team mates.



The site plan of the VARANASI OBSERVATORY

The Varanasi Observatory was, thus, constructed on the terrace of Man Mandir in C. 1737 A.D. by the Royal Astronomber of Jaipur who was assisted by his court-astronomers like Pandit Jagannath Samrat and Pandit Kewal Ram. The foreign missionary scholars who visited the Jaipur and Delhi Observatories are believed to have visited this Observatory as well during the eighteenth century.

One of the earliest descriptions of this treasure - trove of astronomical devices is provided by Sir Robert Barker, Commander-in-Chief of Bengal, who came to Varanasi for an on-the-spot study of this Observatory in 1772 A.D. His article "Brahamins Observatory of Benares" appeared in the transactions of British Royal Society in 1777 A.D. Sir Barker wrote with fascination, 'I cannot quit this subject without observing that the Brahamins,without the assistance of optical glasses, had nevertheless an advantage unexperienced by the observers of the more northern climates. The serenity and the clearness of the atmosphere in the night time in the east Indies, except at the seasons of changing the monsoons or periodical winds, is difficult to express to those who have not seen it, because we have nothing in comparison to form our ideas upon; it is clear to perfection, a total quietude subsists, scarcely a cloud to be seen; and the light of the stars, affords a prospect both of wonder and contemplation."

The Varanasi Observatory finds its pride place in the Encyclopaedia Brittanica's editions till 1823 as "one of the fine celebrated observatories of the world".

This was again the worthy descendant of the astronomer Maharaja, Maharaja Sawai Madho Singh II of Jaipur, who realised the importance of this magnificent monument and took all pains to restore and preserve Varanasi Jantar-Mantar. He sent Pandit Gokul Chand Bhavan, Lala Chimanlal and Bhagirath Mistry (mason) to Varanasi and thus, this 'Vedhashala' was restored in 1911 A.D. at the expense of erstwhile Jaipur State Exchequer.

To-day, the Man Mandir and the Observatory are important monuments of Varanasi. An atmosphere of utter neglect prevails around the Jantar-Mantar which has become a virtual hideout of herds of monkies. There are no guards, keepers or guides posted to protect this monument or help the visitors. This magnificent astronomical monument which is already 250 years old, deserves much more care and immediate restoration by the Archaeological Survey of India as it is a symbol of India's glorious past in the field of astral science.

INSTRUMENTS OF VARANASI OBSERVATORY

(1) EQUATORIAL SUN-DIAL (Samrat Yantra)

THE triangular gnomon makes an angle

equivalent to the latitude of Varanasi and lies in the plane of local meridian (North-South). It is flanked by two quadrants (East-West) which are inclined to the plane of celestial equator. It indicates the Local Varanasi Time which can be converted to the Indian Standard Time by utilising the following Table of Difference of Time.

	5th Mi.Se.	10th Mi.Se.	15th Mi.Se.	20th Mi.Se.	25th Mi.Se.	30th Mi.Se.
JANUARY	3.26	5.36	7.29	9.6	10.25	11.25
FEBRUARY	12.8	12.22	12.17	11.54	11.14	10.44
MARCH	9.42	8.31	7.8	5.31	4.11	2.22
APRIL	0.53	- 0.30	- 1.48	- 2.56	- 3.56	- 4.42
MAY	- 5.16	- 5.36	- 5.39	- 5.29	- 5.7	- 4.23
JUNE	- 3.36	- 3.44	- 1.56	- 0.32	- 0.32	1.34
JULY	2.31	3.21	3.55	4.19	4.30	4.24
AUGUST	4.2	3.24	2.33	1.28	0.11	- 1.34
SEPTEMBER	- 3.18	- 4.52	- 6.39	- 8.26	-10.10	-11.56
OCTOBER	-13.26	-14.50	-16.6	-17.6	-17.48	-18.16
NOVEMBER	-18.19	-18.1	-17.22	-16.20	-15.00	-13.20
DECEMBER	-11.40	- 9.26	- 6.56	- 4.26	- 1.56	1.00

(2) SMALL EQUATORIAL SUN-DIAL AND POLE STAR INSTRUMENT (Laghu Samrat Yantra and Dhruva Darshak Yantra)

This is a smaller version of the above mentioned Yantra.

(3) MERIDINAL WALL INSTRUMENTS (2) (Dakshinovritti Bhitti Yantras)(2)

Two quadrants intersecting each other

at 60 degrees are made on the Eastern face of the Big Equatorial Dial's Central triangular wall which lies accurately in the plane of local meridian (North-South). Two metal pegs (gnomons) are provided on top of both the arcs.

The other Bhitti Yantra is a smaller but identical version of the above mentioned instrument.

(4) CIRCULAR (DECLINATION) INSTRUMENT (Chakra Yantra)

This is the only metal instrument at Varanasi. It rotates in the plane of celestial equator.

(5) HEMISPHERICAL SUN-DIAL (Narivalaya Yantra)

This small Sun-Dial is made inclined to the plane of celestial equator and has a metal gnomon at its centre to cast shadow.

(6) AZIMUTH INSTRUMENT (Digansha Yantra)

This Yantra consists of three circular structures made in the horizontal plane of Varanasi. It has a metal gnomon at its centre.

The above six astronomical devices are identical to their counterparts at the Jaipur Observatory which may be referred to for details of their constructions and functions.

5. MATHURA OBSERVATORY

Latitude 187 Meters (600 Feet) above M.S.L.

Longitude 77°42' East of Greenwich

Latitude 27°28' North

The cruel hands of time have snatched away one of the five magnificent astronomical observatories from us. Not even a debris of the observatory is available at Mathura where Maharaja Sawai Jai Singh had built a number of astronomical instruments around 1738 A.D. For this purpose, he chose the terrace of legendary Fort known as 'Kans-Ka-Kila' where Lord Krishna was born in one of its prison cells. The same Fort was rebuilt and strengthened by Raja Man Singh of Amber, Sawai Jai Singh's ancestor, towardsa the end of the Sixteenth century.

Thus, the Mathura Observatory was located on the terrace of one of the buildings of this Fort situated on the bank of Yamuna. As Mathura, situated on Delhi-Agra Highway, is associated with the childhood of Lord Krishna, it got due consideration from Sawai Jai Singh who was a staunch devotee of Lord Krishna. The Maharaja had built a temple of Lord Krishna, popularly known as 'Govind Devji' that exists even today near the City Palace in Jaipur. The Krishna idol was brought from Vrindaban near Mathura, when that holy place was threatened by the bigot Aurangzeb.

Sawai Jai Singh used to visit and pass through Mathura often when he travelled between Agra and Delhi as the Governor of Agra during the reign of Moghul Emperor Mohammad Shah. Being a sacred place of worship, Mathura was frequented by a great many Hindu Pandits and Brahmin astronomers and astrologers for pilgrimage. Thus, the astronomer - Maharaja of Jaipur realised the political and religious importance of the place and thought of providing the fifth and last of his 'Jantar Mantars' here.

Not much information is available about the Mathura Observatory but according to Kaye's account there were several small instruments which included :

(1) <u>The Amplitude Instrument</u>
(Agra Yantra)

(2) <u>Small Equatorial Sun Dial</u>
(Laghu Samrat Yantra)

(3) <u>Horizontal Sun Dial</u>
(Dhoop Ghari)

(4) <u>Meridinal Wall Instrument</u>
(Dakshinovritti Bhitti Yantra)

These instruments were built in brick and mortar and they were the smaller versions of their counterparts at Jaipur.

Alas, the Mathura Observatory stands in the pages of history only as its venue, the Mathura Fort, was slowly demolished as this ancient holy city withstood repeated attacks by religious

fanatics. The last remains of this observatory were sent into oblivion sometime during the 1857 struggle. Jyoti Prasad, a contractor had bought the Fort from the British Government in 1857 A.D. and demolished the entire military structure to sell out its every bit, thus, destroying the very existence of the Mathura Observatory. However, with this creation at Mathura, Maharaja Sawai Jai Singh of Jaipur accomplished his grand slam of raising five astronomical complexes in the country during the first half of the eighteenth century.

A panoramic view of the Jaipur Observatory

BIRTHSTONES

JAN	:	GARNET
FEB	:	AMETHYST
MAR	:	AQUAMARINE
APR	:	DIAMOND
MAY	:	EMERALD
JUNE	:	PERL/MOONSTONE
JULY	:	RUBY
AUG	:	PERIDOT
SEP	:	SAPPHIRE
OCT	:	OPAL/TOURMALINE
NOV	:	TOPAZ/CITRINE
DEC	:	TURQUOISE/ZIRCON